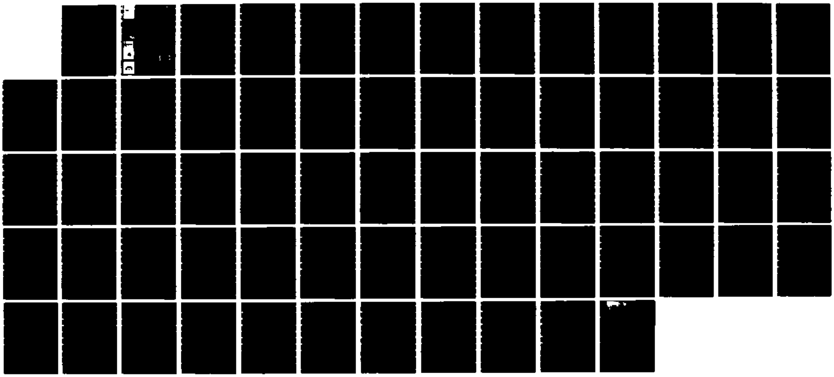
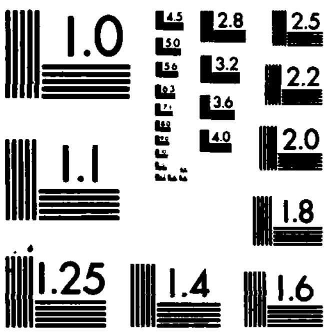
AD-A140 510 HIGH-STRENGTH CONCRETE FOR PEACEKEEPER FACILITIES(U) 1/1
ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS
STRUCTURES LAB K L SAUCIER MAR 84 WES/MP/SL-84-3
UNCLASSIFIED CTIAC-70 F/G 11/2 NL




1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
5.6
6.3

US Army Corps of Engineers

AD-A140 510

STRUCTURES LABORATORY

DTIC FILE COPY

MISCELLANEOUS PAPER SL-84-3

HIGH-STRENGTH CONCRETE FOR PEACEKEEPER FACILITIES

by

Kenneth L. Saucier

Structures Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

March 1984

Final Report

Approved For Public Release; Distribution Unlimited

Prepared for U. S. Army Corps of Engineers
Missile Construction Office
Norton AFB, San Bernardino, Calif. 92409

84 04 25 059

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Miscellaneous Paper SL-84-3	2. GOVT ACCESSION NO. A140 510	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) HIGH-STRENGTH CONCRETE FOR PEACEKEEPER FACILITIES		5. TYPE OF REPORT & PERIOD COVERED Final report
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Kenneth L. Saucier		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U. S. Army Engineer Waterways Experiment Station Structures Laboratory P. O. Box 631, Vicksburg, Miss. 39180		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS U. S. Army Corps of Engineers Missile Construction Office Norton AFB, San Bernardino, Calif. 92409		12. REPORT DATE March 1984
		13. NUMBER OF PAGES 60
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Available from National Technical Information Service, 5285 Port Royal Road, Springfield, Va. 22161.

This is CTIAC Report No. 70.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Peacekeeper
High-range water reducers
High-strength concrete

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

An investigation is described which was conducted to determine the processes and techniques required to produce portland-cement concrete with a compressive strength of 15,000 psi or greater using conventional concreting methods and equipment, and to develop physical property data on the mixtures. It was permitted that special materials and admixtures be used, but a requirement was set that the aggregates and cements be selected from those available in the Cheyenne, Wyoming, area.

(Continued)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. ABSTRACT (Continued)

Results indicated that it is feasible to achieve the 15,000-psi compressive strengths but that workability may decrease over a 2-hour period, and this latter development should be studied under job conditions. It is recommended that (a) all materials and procedures to be used on a specific project be tested in the laboratory for basic property information, and (b) selected mixtures be tested in the field under expected environmental conditions prior to actual job use.

Preface

The investigation described in this report was conducted for the U. S. Army Corps of Engineers Missile Construction Office, Norton AFB, California, by the Concrete Technology Division (CTD) of the Structures Laboratory (SL), U. S. Army Engineer Waterways Experiment Station (WES). Authorization for the investigation was given in DA Form 2544, No. E87 83-7165, dated 21 March 1983.

The investigation was performed under the general supervision of Mr. Bryant Mather, Chief, SL, and Mr. John M. Scanlon, Chief, CTD, and under the direct supervision of Mr. Kenneth L. Saucier, Principal Investigator. Mr. Donald M. Walley, CTD, proportioned the concrete mixtures. This report was prepared by Mr. Saucier.

Funds for publication of this report were provided from those made available for operation of the Concrete Technology Information Analysis Center (CTIAC). This is CTIAC Report No. 70.

Commander and Director of WES during the investigation and the preparation and publication of this report was COL Tilford C. Creel, CE. Technical Director was Mr. F. R. Brown.

Contents

Conversion Factors, Non-SI to SI (Metric)

Units of Measurement

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
inches	0.0254	metres
pounds (force) per square inch	6894.757	pascals
pounds (mass)	0.45359237	kilograms
pounds (mass) per cubic yard	0.5932764	kilograms per cubic metre

HIGH-STRENGTH CONCRETE FOR PEACEKEEPER FACILITIES

Background, Purpose, and Scope

Background

1. Previous work has indicated that concrete with a compressive strength of 10,000 psi* is achievable with present-day technology and materials. Quality materials, use of a low water-cement ratio (W/C), and admixtures are required. More recently the use of more effective admixtures, known as high-range water-reducing admixtures (HRWRA), and a very fine silicon-dioxide powder, known as silica fume, have shown promise for increasing the compressive strength of portland-cement concrete above 10,000 psi.

Purpose

2. The purposes of this program were (a) to conduct a study of the processes and techniques required to produce portland-cement concrete with a compressive strength of 15,000 psi or greater using conventional concreting methods and equipment, and (b) to develop physical property data on the mixtures. Special materials and admixtures were permitted, but the aggregates and cements were selected from those available in the Cheyenne, Wyoming, area.

Scope

3. The study consisted of the necessary investigation of materials and methods to produce 15,000-psi concrete. The slump was allowed to vary between 2 and 8 in. Tests included compressive strength at different ages, tensile strength, elastic properties, resistance to freezing and thawing, shrinkage, creep, and loss of slump with time.

Materials, Mixtures, and Tests

Materials

4. One granite coarse aggregate, designated OM 19 G-1, one limestone aggregate, designated OM 19 G-2, and one limestone sand, designated OM 19 S-1, were received for use in the study. Both project coarse aggregates were washed prior to use. The granite was also screened over a 1-in. sieve to remove

* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 3.

oversize material. In addition, a laboratory rock was used in a number of mixtures when it became apparent that the large number of trial batches required would exhaust the supply of project aggregate before all the physical property tests could be conducted. A local chert aggregate and a local lightweight aggregate were used in several trial mixtures. Aggregate property data on the project aggregates and the laboratory limestone aggregate are given in Tables 1-4.

5. The portland cement was a Type II from Wyoming. Information on the cement is given in Table 5. Results of tests of a Class F fly ash, a Class C fly ash, and the silica fume used in the study are given in Tables 6A, 6B, and 7, respectively.

6. A naphthalene-based HRWRA and a melamine-based HRWRA were used in the study. An air-entraining admixture was used in selected admixtures. Fibers were incorporated in three mixtures on a trial basis.

Mixtures

7. Seventy-six mixtures were proportioned. Results are given in Table 8. In addition to the mixtures given, many batches were discarded when they were found to be harsh or unworkable. The first five mixtures were based on previous experience applied to project material and using the recommended dosage of admixture. Subsequent mixtures introduced the materials and proportions required to provide a comprehensive study of all reasonable combinations. Pertinent information on the mixtures is given in the remarks column of Table 8. Mixing was done according to ASTM C 192-81.

Tests

8. Tests were conducted according to the following ASTM standards:

a. Slump - C 143-78.

b. Compressive strength - C 39-81.

c. Splitting tensile strength - C 496-79.

d. Modulus of elasticity and Poisson's ratio - C 469-81.

e. Resistance to freezing and thawing - C 666-80.

f. Length change on drying - C 157-80.

g. Creep - C 512-82.

9. The compressive strength specimens were 3-in.-diameter by 6-in.-long cylinders cured in water until time of test. Due to the very high test strength, compressive specimens were ground to tolerance on a surface grinder rather than being capped. Electrical resistance strain gages were used to record stress-strain data for calculation of modulus of elasticity and Poisson's ratio.

Results

Proportioning

10. The proportioning work, Table 8, indicated that it is indeed possible to achieve workable, low W/C concrete with various combinations of the selected materials. Slumps in the range up to 8 in. were secured with water-cementitious ratios approximating 0.25 and without segregation or harshness in most instances. During the proportioning study, however, it became apparent that a slight reduction in W/C or slight increase in admixture dosage could instantly change the workability of a mixture. A decrease of 0.01 in W/C could make a mixture very sticky or an increase of 0.1 percent in admixture dosage could result in a harsh mixture. Apparently, these changes are the result of working near the critical minimum amount of water (W/C = 0.25) and the critical maximum dosage of admixture (1.0 percent of cement). The slump test is not a good indicator of workability under these circumstances. A high-slump mixture may consolidate satisfactorily yet be sticky and hard to move. A high-slump mixture may even "flow" during the slump test, but be very harsh. It is not possible to relate the characteristics of the mixture developed herein directly to a field situation due to variations of materials, the chemistry of the cement and admixtures, and the differences in mixing actions and temperature. These mixtures could, however, be used as a basis for field mixtures to be tried under actual job conditions with job equipment.

11. Slump loss tests were conducted on three mixtures, Nos. 38, 48, and 58, to determine loss of workability with time. An initial slump test was conducted immediately after mixing. The concrete was then allowed to be at rest for 25 min, at which time it was remixed for 5 min. This cycle was repeated until the end of the test. Results are given in Table 9. Indications are that some workability will be lost over a period of 2 hr, but the concrete will remain placeable for 2 hr. Redosing with admixture is a viable option for restoring workability, but redosing tests were not conducted in this study. Again, the importance of these tests is to indicate that extended workability is possible to achieve with these mixtures; field tests should be conducted under actual project conditions.

Compressive strength

12. Compressive strength results are given in Table 10. The tests were conducted on 3- by 6-in. cylinders (3 x 6) unless otherwise noted. Indications are that:

a. Compressive strengths of approximately 10,000 psi may be attained at 7-days age with the materials used and the slump specified.

b. Compressive strengths of 12,000 psi may be achieved at 28-days age.

c. Compressive strengths of 15,000 psi may be attained at 90-days age.

d. Compressive strengths of 20,000 psi may be attained with selected mixtures at extended ages.

e. The use of high-range water-reducing admixtures is necessary to achieve the desired strengths at the required slumps.

f. Fly ash and silica fume enhance the potential for increased compressive strength.

g. High-strength, air-entrained concrete containing silica fume is feasible.

h. Fibers may be used in high-strength concrete; however, a significant loss in workability results.

i. Lightweight high-strength (10,000-psi) concrete could not be attained with the materials and techniques used herein.

13. To facilitate comparison of the two project aggregates, strength results are given in Tables 11 and 12 for limestone and granite coarse aggregates, respectively. A cursory examination of the results reveals that the granite aggregate produced slightly higher strengths for comparable mixtures. However, it is obvious that 15,000-psi concrete may be attained with either of the coarse aggregates and selected cementitious materials and admixtures used in the program.

Splitting tensile strength

14. Splitting tensile strength results are given in Table 13. Tensile strengths of approximately 1200 psi were achieved on several mixtures. Thus, the tensile strength is approximately 9 percent of the comparable compressive strength. This compares to the normally accepted value of 10 percent used for conventional concrete.

Elastic properties

15. Stress-strain curves for 18 specimens tested in compression to failure are given in Figures 1-18. The curves for vertical strain are essentially linear to failure. Some nonlinearity is apparent in the horizontal or

circumferential strain. Young's modulus of elasticity and Poisson's ratio results are given in Table 13. Young's modulus for the representative samples tested approximated 6.0×10^6 psi. This is twice the normally accepted value for conventional concrete. Poisson's ratio varied somewhat depending on the curvature of the horizontal strain curve and at what stress level the ratio was computed. Actual values ranged between 0.20 and 0.25.

Drying shrinkage tests

16. Results of length change tests, conducted on mixtures No. 22 and 35, are given in Tables 14-17. All specimens were cured in water in accordance with ASTM C 157. For the control tests, Tables 14 and 16, cement was substituted for silica fume on a weight basis. Thus, the total amount of water and the W/C remained constant for all four mixtures. On the 1-in. unrestrained bars expansion was noted in all mixtures. However, significantly more expansion was noted on the mixtures without silica fume. Approximately 0.004 percent shrinkage was noted with the 3-in. bars on the mixtures containing silica fume at 100-days age.

Resistance to freezing and thawing

17. Tests for resistance to freezing and thawing were conducted on three mixtures; one air-entrained limestone coarse aggregate mixture, one air-entrained granite aggregate mixture, and one nonair-entrained granite mixture. Results are given in Tables 18, 19, and 20. After 300 cycles of freezing and thawing all mixtures had a relative modulus (E) of at least 80 percent. At approximately 350 cycles both granite mixtures (air- and nonair-entrained) had a modulus of about 85 percent but the air-entrained limestone mixture had dropped to approximately 70 percent. At approximately 400 cycles the granite mixtures still had a modulus of approximately 80 percent, but the limestone mixture had dropped to 50 percent. All testing was terminated when the modulus decreased to 50 percent on each of the three mixtures. Apparently, the combination of a very dense rock (granite) and a very low W/C provided excellent resistance to freezing and thawing. It would appear that the nonair-entrained concrete did not achieve critical saturation with water under the test conditions used.

Creep tests

18. Creep tests were conducted on specimens from mixture No. 22 with and without silica fume in accordance with ASTM C 512-82. The creep load was 2000 psi. Results for total strain, creep strain, and specific creep up to 3-months age are given in Figures 19-24. At 90-days age indications are that (a) creep is essentially equal for mixtures with and without silica fume, (b) total strain approximated 500 millionths, (c) creep strain approximated 200 millionths, and (d) specific creep was approximately 0.1 millionth per psi.

Conclusions

19. The results of this investigation indicate the following:

a. It is feasible to achieve 15,000-psi compressive strength concrete with selected cementitious materials and aggregates from the Wyoming area.

b. Some workability may be lost over a time period of 2 hr; thus, this phenomenon should be investigated under job conditions.

c. Tensile strengths approximating 1200 psi were achieved. Modulus of elasticity was approximately 6.0×10^6 psi and Poisson's ratio was approximately 0.20.

d. Shrinkage of typical high-strength concrete containing silica fume was indicated to be on the order of 0.004 percent at 100 days in water.

e. Freeze-thaw-resistant concrete was achieved with both project aggregates in an air-entrained mixture. In addition, a nonair-entrained mixture with the granite aggregate developed significant freeze-thaw resistance.

f. Creep was essentially equal for mixtures with and without silica fume, approximating 200 millionths of strain at 3-months age under 2000 psi of stress.

Recommendations

20. It is recommended that (a) all materials and procedures to be used on a specific project be tested in the laboratory for basic property information, and (b) selected mixtures be tested in the field under expected environmental conditions prior to actual job use.

Table 1

STATE	INDEX NO.	**AGGREGATE DATA SHEET**	TESTED BY: TGR
LAT.	LONG.		DATE: 29 April 1983

LAB SYMBOL NO.: OM19 G-1 TYPE OF MATERIAL: Granite No. 4 to 1 in.

LOCATION: Granite Canyon, Wyoming
Omaha District

PRODUCER:

SAMPLED BY: Omaha District

TESTED FOR:

USED AT:

PROCESSING BEFORE TESTING:

GEOLOGICAL FORMATION AND AGE:

GRADING (CRD-C 103) (CUM. % PASSING):

SIEVE	3-6"	1½-3"	¾-1½"	#4-1"	FINE AGG.
6 IN.					
5 IN.					
4 IN.					
3 IN.					
2½ IN.					
2 IN.					
1½ IN.				100	
1 IN.				100	
¾ IN.				89	
½ IN.				39	
⅜ IN.				15	
NO. 4				1	
NO. 8				1	
NO. 16					
NO. 30					
NO. 50					
NO. 100					
NO. 200					
-200(a)					
F.M.(b)					

(a) CRD-C 105 (b) CRD-C 104

TEST RESULTS	3-6"	1½-3"	¾-1½"	#4-1"	FINE AGG.
BULK SP GR, S.S.D. (CRD-C 107, 108)				2.68	
ABSORPTION, % (CRD-C 107, 108):				0.59	
ORGANIC IMPURITIES, FIG. NO. (CRD-C 121)	—	—	—	—	
SOFT PARTICLES, % (CRD-C 130)					—
% LIGHTER THAN SP GR ____ (CRD-C 122)					
% FLAT AND ELONGATED (CRD-C 119, 120)					
WT AV % LOSS, 5 CYC $MgSO_4$ (CRD-C 115)					
L.A. ABRASION LOSS, % (CRD-C 117, 145) GRADING ____					
UNIT WT, LB/CU FT (CRD-C 106):					
FRIABLE PARTICLES, % (CRD-C 142)					
SPEC HEAT, BTU/LB/DEG F. (CRD-C 124)					
REACTIVITY WITH NaOH (CRD-C 128): Sc, mM/L:					
Rc, mM/L:					

MORTAR-MAKING PROPERTIES (CRD-C 116)
TYPE ____ CEMENT, RATIO: ____ DAYS, ____ %, ____ DAYS, ____ %

LINEAR THERMAL EXPANSION, MILLIONTHS/DEG F. (CRD-C 125, 126):

ROCK TYPE	PARALLEL	ACROSS	ON	AVERAGE

MORTAR:

MORTAR-BAR EXPANSION AT 100F, % (CRD-C 123):		FINE AGGREGATE				COARSE AGGREGATE			
		2 MO.	6 MO.	9 MO.	12 MO.	3 MO.	6 MO.	9 MO.	12 MO.
LOW-ALK. CEMENT:	% Na_2O EQUIVALENT:								
HIGH-ALK. CEMENT:	% Na_2O EQUIVALENT:								

SOUNDNESS IN CONCRETE (CRD-C 40, 114):			F&T	HW-CD	HD-CW
FINE AGG.	COARSE AGG:	DFE_{300}			
FINE AGG.	COARSE AGG:	DFE_{300}			

PETROGRAPHIC DATA (CRD-C 127):

REMARKS:

ENG FORM 1 MAR 1968 6011-R

Table 2

STATE:	INDEX NO.:	**AGGREGATE DATA SHEET**	TESTED BY: TGR
LAT.:	LONG.:		DATE: 29 April 1983

LAB SYMBOL NO.: OM19 G-2 TYPE OF MATERIAL: Limestone No. 4 to 1 in.

LOCATION: Granite Canyon, Wyoming
Omaha District

PRODUCER: G. W. Sugar; Harriman, Wyoming

SAMPLED BY: Omaha District

TESTED FOR:

USED AT:

PROCESSING BEFORE TESTING:

GEOLOGICAL FORMATION AND AGE:

GRADING (CRD-C 103) (CUM. % PASSING):

SIEVE	3-6"	1½-3"	¾-1½"	#4-1"	FINE AGG.
6 IN.					
5 IN.					
4 IN.					
3 IN.					
2½ IN.					
2 IN.					
1½ IN.				100	
1 IN.				99	
¾ IN.				64	
½ IN.				27	
⅜ IN.				14	
NO. 4				1	
NO. 8				0	
NO. 16					
NO. 30					
NO. 50					
NO. 100					
NO. 200					
-200(a)					
F.M.(b)					

(a) CRD-C 105 (b) CRD-C 104

TEST RESULTS	3-6"	1½-3"	¾-1½"	#4-1"	FINE AGG.
BULK SP. GR. S.S.D. (CRD-C 107, 108)				2.69	
ABSORPTION, % (CRD-C 107, 108):				0.44	
ORGANIC IMPURITIES, FIG. NO. (CRD-C 121)	—	—	—	—	
SOFT PARTICLES, % (CRD-C 130)					—
% LIGHTER THAN SP GR ____ (CRD-C 122)					
% FLAT AND ELONGATED (CRD-C 119, 120)					
WT AV % LOSS, 5 CYC $MgSO_4$ (CRD-C 115)					
L.A. ABRASION LOSS, % (CRD-C 117, 145) GRADING ____					
UNIT WT, LB/CU FT (CRD-C 106):					
FRIABLE PARTICLES, % (CRD-C 142)					
SPEC HEAT, BTU/LB/DEG F. (CRD-C 124)					
REACTIVITY WITH NaOH (CRD-C 128): Sc, mM/L:					
REACTIVITY WITH NaOH (CRD-C 128): Rc, mM/L:					

MORTAR-MAKING PROPERTIES (CRD-C 116)

TYPE ____ CEMENT, RATIO: ____ DAYS, ________ %, ________ DAYS, ________ %

LINEAR THERMAL EXPANSION, MILLIONTHS/DEG F. (CRD-C 125, 126):

ROCK TYPE	PARALLEL	ACROSS	ON	AVERAGE

MORTAR:

MORTAR-BAR EXPANSION AT 100F, % (CRD-C 123):	FINE AGGREGATE 2 MO.	FINE AGGREGATE 6 MO.	FINE AGGREGATE 9 MO.	FINE AGGREGATE 12 MO.	COARSE AGGREGATE 3 MO.	COARSE AGGREGATE 6 MO.	COARSE AGGREGATE 9 MO.	COARSE AGGREGATE 12 MO.
LOW-ALK. CEMENT: % Na_2O EQUIVALENT:								
HIGH-ALK. CEMENT: % Na_2O EQUIVALENT:								

SOUNDNESS IN CONCRETE (CRD-C 40, 114):	F&T	HW-CD	HD-CW
FINE AGG. COARSE AGG: DFE_{300}			
FINE AGG. COARSE AGG: DFE_{300}			

PETROGRAPHIC DATA (CRD-C 127):

REMARKS:

ENG FORM 1 MAR 1968 6011-R

Table 3

STATE	INDEX NO.	**AGGREGATE DATA SHEET**	TESTED BY: TGR
LAT.	LONG.		DATE: 29 April 1983

LAB SYMBOL NO.: OM19 S-1 TYPE OF MATERIAL: Limestone Sand

LOCATION: Granite Canyon, Wyoming
Omaha District

PRODUCER:

SAMPLED BY: Omaha District

TESTED FOR:

USED AT:

PROCESSING BEFORE TESTING:

GEOLOGICAL FORMATION AND AGE:

GRADING (CRD-C 103) (CUM. % PASSING):

SIEVE	3-6"	1½-3"	¾-1½"	#4-¾"	FINE AGG.
6 IN.					
5 IN.					
4 IN.					
3 IN.					
2½ IN.					
2 IN.					
1½ IN.					
1 IN.					
¾ IN.					
½ IN.					
⅜ IN.					
NO. 4					100
NO. 8					83
NO. 16					63
NO. 30					42
NO. 50					16
NO. 100					5
NO. 200					
-200[a]					
F.M.[b]					2.92

(a) CRD-C 105 (b) CRD-C 104

TEST RESULTS

	3-6"	1½-3"	¾-1½"	#4-¾"	FINE AGG.
BULK SP. GR., S.S.D. (CRD-C 107, 108)					2.62
ABSORPTION, % (CRD-C 107, 108):					0.71
ORGANIC IMPURITIES, FIG. NO. (CRD-C 121)	—	—	—	—	
SOFT PARTICLES, % (CRD-C 130)					—
% LIGHTER THAN SP GR ____ (CRD-C 122)					
% FLAT AND ELONGATED (CRD-C 119, 120)					
WT AV % LOSS, 5 CYC $MgSO_4$ (CRD-C 115)					
L.A. ABRASION LOSS, % (CRD-C 117, 145) GRADING ____					
UNIT WT, LB/CU FT (CRD-C 106):					
FRIABLE PARTICLES, % (CRD-C 142)					
SPEC HEAT, BTU/LB/DEG F. (CRD-C 124)					
REACTIVITY WITH NaOH (CRD-C 128): Sc, mM/L:					
REACTIVITY WITH NaOH (CRD-C 128): Rc, mM/L:					

MORTAR-MAKING PROPERTIES (CRD-C 116)
TYPE ____ CEMENT, RATIO: ____ DAYS, ____ %, ____ DAYS, ____ %

LINEAR THERMAL EXPANSION, MILLIONTHS/DEG F. (CRD-C 125, 126):

ROCK TYPE	PARALLEL	ACROSS	ON	AVERAGE

MORTAR:

MORTAR-BAR EXPANSION AT 100F, % (CRD-C 123):	FINE AGGREGATE 2 MO.	6 MO.	9 MO.	12 MO.	COARSE AGGREGATE 3 MO.	6 MO.	9 MO.	12 MO.
LOW-ALK. CEMENT: % Na_2O EQUIVALENT:								
HIGH-ALK. CEMENT: % Na_2O EQUIVALENT:								

SOUNDNESS IN CONCRETE (CRD-C 40, 114):	F&T	HW-CD	HD-CW
FINE AGG. COARSE AGG. DFE_{300}			
FINE AGG. COARSE AGG. DFE_{300}			

PETROGRAPHIC DATA (CRD-C 127):

REMARKS:

ENG FORM 1 MAR 1969 6011-R

Table 4

STATE: Ala.	INDEX NO.: 6 (Suppl 7)	**AGGREGATE DATA SHEET**	TESTED BY: USAEWES
LAT: 33 N	LONG: 86 W		DATE: 3 Feb 1975

LAB SYMBOL NO.: CL-2 G-1, Ms-1 TYPE OF MATERIAL: Limestone

LOCATION: Sec. 8, T 22 S, R 2 W, 1-1/2 miles NW of Calera, Ala. (Calera Quarry)

PRODUCER: Vulcan Materials Co., Birmingham, Ala.

SAMPLED BY: USAEWES

TESTED FOR: Laboratory Stock

USED AT: USAEWES

PROCESSING BEFORE TESTING:

GEOLOGICAL FORMATION AND AGE:

GRADING (CRD-C 103) (CUM. % PASSING):

SIEVE	3-6"	1½-3	¾-1½"	#4-¾"	FINE AGG.
6 IN.					
5 IN.					
4 IN.					
3 IN.					
2½ IN.					
2 IN.					
1½ IN.					
1 IN.			100		
¾ IN.			96		
½ IN.			47		
⅜ IN.			19		
NO. 4			0		
NO. 8					
NO. 16					
NO. 30					
NO. 50					
NO. 100					
NO. 200					
-200[a]					
F.M.[b]					

(a) CRD-C 105 (b) CRD-C 104

TEST RESULTS	3-6"	1½-3	¾-1½"	#4-¾"	FINE AGG.
BULK SP. GR., S.S.D. (CRD-C 107, 108)				2.69	
ABSORPTION, % (CRD-C 107, 108)				0.5	
ORGANIC IMPURITIES, FIG. NO. (CRD-C 121)	—	—	—	—	
SOFT PARTICLES, % (CRD-C 130)					—
% LIGHTER THAN SP GR ____ (CRD-C 122)					
% FLAT AND ELONGATED (CRD-C 119, 120)					
WT AV % LOSS, 5 CYC $MgSO_4$ (CRD-C 115)					
L.A. ABRASION LOSS, % (CRD-C 117, 145) GRADING ____					
UNIT WT, LB/CU FT (CRD-C 106)					
FRIABLE PARTICLES, % (CRD-C 142)					
SPEC HEAT, BTU/LB/DEG F. (CRD-C 124)					
REACTIVITY WITH NaOH (CRD-C 128): Sc, mM/L					
REACTIVITY WITH NaOH (CRD-C 128): Rc, mM/L					

MORTAR-MAKING PROPERTIES (CRD-C 116)
TYPE ____ CEMENT, RATIO: ____ DAYS, ____ %, ____ DAYS, ____ %

LINEAR THERMAL EXPANSION, MILLIONTHS/DEG F. (CRD-C 125, 126):

ROCK TYPE	PARALLEL	ACROSS	ON	AVERAGE

MORTAR:

MORTAR-BAR EXPANSION AT 100F, % (CRD-C 123):	FINE AGGREGATE 2 MO.	6 MO.	9 MO.	12 MO.	COARSE AGGREGATE 3 MO.	6 MO.	9 MO.	12 MO.
LOW-ALK. CEMENT: % Na_2O EQUIVALENT:								
HIGH-ALK. CEMENT: % Na_2O EQUIVALENT:								

SOUNDNESS IN CONCRETE (CRD-C 40, 114):	F&T	HW-CD	HD-CW
FINE AGG. COARSE AGG. DFE_{300}			
FINE AGG. COARSE AGG. DFE_{300}			

PETROGRAPHIC DATA (CRD-C 127):

REMARKS:

ENG FORM 1 MAR 1968 6011-R

Table 5

TO: Structures Laboratory Waterways Exp Station ATTN: Ken Saucier P. O. Box 631 Vicksburg, MS 39180	REPORT OF TESTS OF PORTLAND CEMENT RC 894	FROM: CORPS OF ENGINEERS U. S. ARMY Structures Laboratory Waterways Exp Station ATTN: Cem & Pozz Unit P. O. Box 631 Vicksburg, MS 39180

TEST REPORT NO. WES-171-83	BIN NO	CWT REPRESENTED	DATE: 2 May 83
SPECIFICATION: ASTM C 150, II,High Strength		DATE SAMPLED: 21 April 1983	
COMPANY: Monolith	LOCATION: Laramie, WY	BRAND:	

THIS CEMENT DOES X MEET SPECIFICATION REQUIREMENTS

SAMPLE NO	1								
SiO_2, %	20.6								
Al_2O_3, %	4.3								
Fe_2O_3, %	3.2								
MgO, %	0.9								
SO_3, %	2.8								
LOSS ON IGNITION, %	2.3								
ALKALIES-TOTAL AS Na_2O, %	0.35								
Na_2O, %	0.12								
K_2O, %	0.35								
INSOLUBLE RESIDUE, %	0.52								
CaO, %	64.5								
C_3S, %	65								
C_3A, %	6								
C_2S, %	10								
$C_3A + C_3S$, %	71								
C_4AF, %	10								
$C_4AF + 2\ C_3A$, %	22								
HEAT OF HYDRATION, 7D, CAL/G									
HEAT OF HYDRATION, 28D, CAL/G									
SURFACE AREA, SQ CM/G (A.P.)	4030								
AIR CONTENT, %	8								
COMP. STRENGTH, 3 D, PSI	3600								
COMP. STRENGTH, 7 D, PSI	4770								
COMP. STRENGTH 28 D, PSI *	6090								
FALSE SET-PEN. F I, %									
SAMPLE NO.	1								
AUTOCLAVE EXP., %	0.02								
INITIAL SET, HR/MIN	2:45								
FINAL SET, HR/MIN	4:25								
SAMPLE NO.									
AUTOCLAVE EXP., %									
INITIAL SET, HR/MIN									
FINAL SET, HR/MIN									

REMARKS: High Strength Concrete Program - Ken Saucier

cc: Don Walley

R. E. Reinhold

R. E. REINHOLD
Chief, Cement & Pozzolan Unit

ENG FORM 1 MAR 72 6008-R

Table 6A

LABORATORY: Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P.O. Box 631 Vicksburg, MS 39180	REPORT OF TESTS ON POZZOLAN SS-C-1960/5 AD-590	REPORT NO.: WES-319F-79 SHEET 1 OF 1 DATE: 16 July 79 6 August 79

CLASS (F) N — KIND OF POZZOLAN: Fly Ash

SOURCE: Williams Bros., Atlanta, GA — BRAND:

TEST RESULTS OF THIS SAMPLE LOT [X] COMPLY [ ] DO NOT COMPLY WITH SPECIFICATION LIMITS (SEE REMARKS)

FOR USE AT:

CONTRACT NO.:

DISTRICT(S):

SAMPLED BY: Structures Branch — DATE SAMPLED: 2 July 79

CAR NO.: — BIN NO.:

FIELD SAMPLE NO.: — LAB SAMPLE NO.:

DATE RECEIVED: 2 July 79 — LAB JOB NO.:

TESTED BY: Cem & Pozz Testing Branch — CHECKED BY:

TESTS ON COMPOSITE OF THE 100-TON SAMPLES LISTED BELOW

$SiO_2 + Al_2O_3 + Fe_2O_3$ %	MgO %	SO_3 %	AVAILABLE ALKALIES %	POZZOLAN STRENGTH % CONTROL	INCREASE IN SHRINKAGE % (a)	AUTOCLAVE EXPANSION %	REDUCTION IN EXPANSION % (b)
REQUIREMENTS							
MIN 70.0	MAX 5.0	MAX 4.0	MAX 1.5	MIN 75	MAX 0.03	MAX 0.50	MIN 75
TEST RESULTS							
88.5	1.3	0.7	* 0.65	* 91		0.03	

TESTS ON SAMPLES REPRESENTING 100 TONS OR LESS

SAMPLE NO.	MOISTURE CONTENT %	LOSS ON IGNITION %	Fineness 325 Mesh Sieve % Retained	% pts var from avg prev 10	LIME POZZOLAN STRENGTH PSI 2" cubes	WATER REQUIREMENT % of Control	SPECIFIC GRAVITY	SP GR VARIATION FROM AVERAGE OF PRECEDING 10, %
REQUIREMENTS								
—	MAX 3.0	MAX 10.0 (N) 6.0 (F)	MAX 34	MAX 5	MIN 900	MAX 105	—	MAX 5
TEST RESULTS								
1	0.5	2.0	21		1120	97	2.43	
AVERAGE	—	—		—	—	—		—

(a) APPLICABLE ONLY TO CLASS N — LABORATORY CEMENT USED Alpha, Birmingham, AL, WES-216-79

(b) OPTIONAL REQUIREMENT — LABORATORY LIME USED Chemstone

REMARKS: Meets 7 day specification requirements. *28 day test report

441-S920.19SC42

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

NOTE: THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U. S. GOVERNMENT.

ENG FORM NO. 6000-R
1 AUG 67

Table 6B

LABORATORY	REPORT OF TESTS ON POZZOLAN	REPORT NO.
Structures Laboratory Waterways Exp Station ATTN: Cem & Pozz Unit P. O. Box 631 Vicksburg, MS 39180	AD 712	WES-42C-83 SHEET 1 OF 1 DATE 23 February 1983 23 March 1983

CLASS F (C 'N KIND OF POZZOLAN:

SOURCE: Bayou Ash, New Roads, LA BRAND:

TEST RESULTS OF THIS SAMPLE LOT ☒ COMPLY ☐ DO NOT COMPLY WITH SPECIFICATION LIMITS (SEE REMARKS)

FOR USE AT: Old River Auxiliary Structure

CONTRACT NO.:

DISTRICT(S):

SAMPLED BY: DATE SAMPLED: 8 Feb 83

CAR NO.: BIN NO.:

FIELD SAMPLE NO.: LAB SAMPLE NO.:

DATE RECEIVED: 11 Feb 83 LAB JOB NO.:

TESTED BY: Cem & Pozz Unit CHECKED BY:

TESTS ON COMPOSITE OF THE 100-TON SAMPLES LISTED BELOW

$SiO_2 + Al_2O_3 + Fe_2O_3$ %	MgO %	SO_3 %	AVAILABLE ALKALIES %	POZZOLAN STRENGTH % CONTROL	INCREASE IN SHRINKAGE % (a)	AUTOCLAVE EXPANSION %	REDUCTION IN EXPANSION % (b)
REQUIREMENTS							
MIN 70.0	MAX 5.0	MAX 5.0	MAX 1.50	MIN 75	MAX 0.03	MAX 0.8	MIN 75
TEST RESULTS							
59.0	5.5	3.2		* 105		-0.01	

TESTS ON SAMPLES REPRESENTING 100 TONS OR LESS

SAMPLE NO.	MOISTURE CONTENT %	LOSS ON IGNITION %	Fineness 325 Mesh Sieve % Retained	% pts var from avg prev 10	LIME POZZOLAN STRENGTH PSI	WATER REQUIREMENT % of Control	SPECIFIC GRAVITY	SP GR VARIATION FROM AVERAGE OF PRECEDING 10, %
REQUIREMENTS								
—	MAX 3.0	MAX 10.0 (N) 6.0 (F)	MAX 34	MAX 5	MIN 900	MAX 105	—	MAX 5
TEST RESULTS								
1	0.1	0.2	12	2	1830	98	2.75	2
CaO %: 25.0								
AVERAGE								

(a) APPLICABLE ONLY TO CLASS N LABORATORY CEMENT USED Arkansas, Foreman, ARK

(b) OPTIONAL REQUIREMENT LABORATORY LIME USED Chemstone

REMARKS: Meets 7 day specification requirements, *28 day test results

R. E. Reinhold

R. E. REINHOLD
Chief, Cement & Pozzolan Unit

NOTE: THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U. S. GOVERNMENT.

ENG FORM NO. 6000-R
1 AUG 67

Table 7

CORRECTED 12 APRIL 1983

LABORATORY Structures Laboratory Waterways Exp Station ATTN: Cem & Pozz Unit P. O. Box 631 Vicksburg, MS 39180	**REPORT OF TESTS ON POZZOLAN** AD 536(5)	REPORT NO.: WES-43S-83 SHEET 1 OF 2 DATE: 23 February 1983 28 March 1983

CLASS F N | KIND OF POZZOLAN Silica Fume

SOURCE: Reynolds Metals, Sheffield, Ala | BRAND:

TEST RESULTS OF THIS SAMPLE LOT ☐ COMPLY ☒ DO NOT COMPLY WITH SPECIFICATION LIMITS (SEE REMARKS)

Fineness (AP) m^2/kg: 2584, e=0.727
" " " ": 3806, e=0.700
" " " ": 4783, e=0.678
Extrapolated m^2/kg:12780, e=0.500, Correlation Coefficent: -1
Date Sampled: 10 Feb 83

FIELD SAMPLE NO.:	LAB SAMPLE NO.:
DATE RECEIVED: 11 Feb 83	LAB JOB NO.:
TESTED BY: Cem & Pozz Unit	CHECKED BY:

TESTS ON COMPOSITE OF THE 100-TON SAMPLES LISTED BELOW

$SiO_2 + Al_2O_3 + Fe_2O_3$ %	MgO %	SO_3 %	AVAILABLE ALKALIES %	POZZOLAN STRENGTH % CONTROL	INCREASE IN SHRINKAGE % (a)	AUTOCLAVE EXPANSION %	REDUCTION IN EXPANSION % (b)
REQUIREMENTS							
MIN 70.0	MAX 5.0	MAX 5.0	MAX 1.50	MIN 75	MAX 0.03	MAX 0.8	MIN 75
TEST RESULTS							
				* 109		-0.14	

TESTS ON SAMPLES REPRESENTING 100 TONS OR LESS

SAMPLE NO.	MOISTURE CONTENT	LOSS ON IGNITION	Fineness 325 Mesh Sieve % Retained	% pts var from avg prev 10	LIME POZZOLAN STRENGTH PSI	WATER REQUIREMENT % of Control	SPECIFIC GRAVITY	SP GR VARIATION FROM AVERAGE OF PRECEDING 10, %
REQUIREMENTS								
—	MAX 3.0	MAX 10.0 (N) 6.0 (F)	MAX 34	MAX 5	MIN 900	MAX 105	—	MAX 5
TEST RESULTS								
1			1	-	2140	* 120	2.25	-
Heat of Hydration								
Portland Cement, RC 883(4)						:	W/C:0.27	W/C:0.40
					7 days:		56	75 cal/gm
					28 days:		62	83 "
RC883(4), 85g + AD536(5), 15g + Hi range WRA 4g :								
					7 days:		50	53 "
					28 days:		48	61 "
AVERAGE	—	—		—	—	—		—

(a) APPLICABLE ONLY TO CLASS N
(b) OPTIONAL REQUIREMENT

LABORATORY CEMENT USED United, Artesia, MS
LABORATORY LIME USED Chemstone

REMARKS *Fails water requirement.

R. E. Reinhold
R. E. REINHOLD
Chief, Cement & Pozzolan Unit

NOTE: THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U. S. GOVERNMENT.

ENG FORM NO. 6000-R
1 AUG 67

TABLE 8 HIGH-STRENGTH MIXTURES

Mix-ture No.	Rock Type	Cement/ Sil. Fume/ Fly Ash/ lb/cu yd	W/C By wt cmt mtls	% HRWR per 100 # cmt mtls	Slump in.	S/A %	Remarks
1	LS	940	0.27	0.5	1/2	38	Slump too low; used D-19 HRWR admixture.
2	LS	940	0.28	0.5	2-3/4	38	Upped the W/C for more slump.
3	LS	940	0.30	0.5	2	38	Upped the W/C again.
4	LS	940	0.32	0.5	5-1/2	38	Upped the W/C again. Increased slump.
5	LS	940	0.32	0.5	6-1/2	40	Upped the S/A. Got the slump.
6	WES	940	0.28	0.5	1	38	Concerned about high W/C and strength. Lowered S/A. Used WES rock.
7	LS	799/141	0.30	0.5-0.8	1 to 6	38	First fume mix (15%). Increase to 0.8 HRWR makes big slump diff.
8	WES	799/141	0.30	0.5	1-1/4	38	Repeat of last mix using WES rock and 0.5 HRWR.
9	WES	799/141	0.28	0.7-0.8	1-1/2 to 6-1/2	38	Repeat of last mix lowering W/C, upping HRWR using WES rock.
10	WES	799/141	0.26	0.8	1-1/2	38	Repeat of last mix lowering W/C even more and upping HRWR to 0.8.
11	WES	799/141	0.30	0.8	6-3/4	40	Repeat of No. 8 increasing HRWR to 0.8 and S/A to 40% for workability.
12	LS	799/141	0.28	0.8	1	38	Modification of No. 7 decreasing the W/C and using 0.8 HRWR. Too stiff.
13	LS	799/141	0.28	0.8	2	38	Repeat of last one using 0.28 W/C at the beginning. Acceptable.
14	LS	799/141	0.30	0.8	6	38	Upped W/C; still concerned that W/C of 0.30 too high.
15	WES	859/139	0.24	1.86	9-1/2	40	Upped HRWR, upped S/A, lowered W/C; error increased CMT and decreased fume.
16	WES	859/139	0.24	1.16	8	40	Lowered HRWR and slump just fell inside criteria.
17	WES	859/139	0.24	0.93	2-1/2	40	Brought HRWR down some more, slump came down with it. O.K.
18	WES	799/141	0.24	1.25	3-1/4	40	Just to see what No. 15 would look like using right CMT & fume. O.K.
19	WES	799/141	0.26	1.0-1.25	3 to 9	40	Upped the W/C to See if 1.0 HRWR would compare to 1.25 at 0.24 W/C. It did.
20	WES	658/141/141	0.24	1.0		40	First fume-fly ash mixture (15% each by weight). Looked good.
21	LS	799/141	0.24	1.0	3	40	Slightly harsh; vibrated O.K.
22	LS	959/169	0.24	1.0	7-3/4	40	Better looking than 21; less harsh; vibrated well.
23	LS	959/169	0.22	1.0	3-1/2	40	Lowered W/C; same as 22; looked good.
24	G	940	0.24	1.0	8	40	Sticky; vibrated, but hard to work with.
25	G	940	0.22	1.0	3	40	Very sticky; balled up; added 0.2% HRWR to make placeable.
26	G	799/141	0.24	1.0	3-1/2	40	Not sticky, but harsh; appearance of being wet.

TABLE 8 (CONTINUED)

Mixture No.	Rock Type	Cement/ Sil. Fume/ Fly Ash/ lb/cu yd	W/C By wt cmt mtls	% HRWR per 100 # cmt mtls	Slump in.	S/A %	Remarks
27	G	799/141	0.26	1.0	7	40	Looked better than No. 26; vibrated well.
28	LS	799/141	0.24	1.0	3	45	Made to compare to No. 21. Worked good; sand helped.
29	G	799/0/141	0.24	1.0	3	40	Very sticky; vibrated well; slump cone flowed; 2 min. extra mixing.
30	LS	799/0/141	0.24	1.0	2-1/2	40	Very sticky; vibrated well; slump cone flowed; 2 min. extra mixing.
31	G	902/226	0.20	1.0	2-3/4	40	Not at all sticky; vibrated very well.
32	LS	658/141/0	0.24	1.0	7	40	Left out the fly ash by error.
33	LS	658/141/ 141	0.24	1.0	3-1/2	40	Got it right this time. Very good mix; not sticky; vibrated easily.
34	G	658/141/141	0.24	1.0	3-1/2	40	#20 with project granite. Handled as good as No. 33.
35	G	959/169	0.24	1.0	8	40	No. 22 mix with project granite. Almost too wet. Not at all sticky.
36	G	799/141	0.26	1.0	4	40	This is mix No. 27 over again using project granite; unscreened, uncrushed, unwashed.
37	LS	658/141/141	0.24	1.0	6-1/2	40	This is mix No. 33 over again using project rock, unscreened, unwashed.
38	WES	799/141	0.30	30 oz.	9	40	First mixture using Rheobuild 561 HRWR; not at all sticky; good vibrating.
39	WES	799/141	0.28	0.8	6-3/4	40	Air trial mixture; used D-19 HRWR. It took 4 oz. to entrain 5.3% air.
40	WES	799/141	0.30	40 oz.	8	40	First Melment (33%) mixture; not sticky; 7.4% air; finished good.
41	WES	799/141	0.26	40 oz.	4	40	Melment again; 3.5% entrained air; good mix in all respects.
42	WES	799/141	0.24	25.5 oz.	1-3/4	40	
43	WES	898/100	0.24	1.16	9	40	Mix 16 using 10% silica fume replacement of cement.
44	WES	799/141	0.24	1.00	3-1/2	40	Rheobuild 561 HRWR; 1% solids.
45	WES	798/200	0.24	1.16	5	40	Mix 16 with 20% silica fume replacement of cement.
46	WES	799/141	0.30	8 oz.	8-3/4	40	4.5% air entrained.
47	WES	859/139	0.24	2.00	10	40	Accidentally doubled HRWR; got 10-in. slump for 3 hr.
48	WES	859/139	0.24	1.00	3-1/4	40	Maintained 3-1/4-in. slump for 2 hr.
49	WES	859/139	0.24	1.16	1/4	40	Mix No. 16 with 200 cu yd steel fibers (0.010 x 0.022 x 1.00 in.).
50	WES	799/141	0.24	1.00	8	40	Substitute Class C fly ash for silica fume on weight basis.

TABLE 8 (CONCLUDED)

Mixture No.	Rock Type	Cement Sil. Fume/ Fly Ash/ lb/cu yd	W/C By wt cmt mtls	% HRWR per 100 # cmt mtls	Slump in.	S/A %	Remarks
51	WES	752/188	0.24	1.00	9-1/4	40	20% by weight cementitious materials substituted with Class C fly ash.
52	WES	658/282	0.24	1.00	8-1/4	40	30% by weight cementitious materials substituted with Class C fly ash.
53	WES	798/200	0.42	1.16	10	40	Mix with special cement; unsuccessful.
54	Chert	799/141	0.29	1.00	5-1/2	40	Good mix; vibrated well.
55	WES	658/141/141	0.24	1.16	8	40	
56	Chert	780/160/0	0.24	2.00		40	Control for mix 57; used Melgran.
57	Chert	780/160/0	0.24			40	2% calcium chloride used; very stiff; no slump test.
58	WES	799/141/0	0.24	1.25	8-1/2	40	
59	WES	859/139/0	0.24	1.16	1/4	40	Repeat of mix 16 using 1-in. fiberglass fibers = 14.8#/cu yd.
60	WES	859/139/0	0.24	1.16	1/2	40	Repeat of mix 16 using fiberglass fibers = 24.3#/cu yd.
61	WES	859/139/0	0.24	1.16	1/2	40	Repeat of mix 16 using polypropylene fibers = 14.8#/cu yd.
62	WES	799/141	0.24	1.25		40	Attempt to entrain air; batch discarded.
63							Not cast.
64	WES	799/141	0.24	1.25	8-1/2	40	Air entrained for freeze/thaw beams (4.6%).
65	WES	799/141	0.24	1.25	9-1/4	40	Non-air-entrained; control for mix 64.
66	LS	799/141	0/24	1/25	8-1/2	40	Air entrained for freeze/thaw beams (4.0%).
67	G	799/141/0	0.24	1.24	8-1/2	40	Air entrained at 2.5%; added AEA to get 5.8%.
68	G	799/141/0	0.24	1.25	9	40	Control for mix 67.
69	LS	846/94/0	0.24	1.25	7	40	
70	LTW	799/141/0	0.24	1.25	2	39.5	3/8-in. expanded clay lightweight coarse aggregate (119.7#/cu ft).
71	LTW	879/155/0	0.24	1.25	10-1/2	45	3/8-in. expanded clay lightweight coarse aggregate (116.9#/cu ft).
72	LTW	959/169/0	0.22	1.25	11	45	Lightweight aggregate. Wet unit weight = 121.2#/cu ft; 4.0% air.
73	LS	959/169/0	0.24	1.0	7	40	Repeat of mix 22; cast creep and shrinkage specimens.
74	LS	1143/0/0	0.24	1.0	7	40	Repeat of mix 22 without silica fume. Cast shrinkage specimens.
75	G	959/169/0	0.24	1.0	8	40	Repeat of mix 35. Cast creep and shrinkage specimens.
76	G	1128/0/0	0.24	1.0	8	40	Repeat of mix 35 without silica fume. Cast shrinkage specimens.

NOTE: Aggregates: LS - Project Limestone
WES - Laboratory Limestone
G - Project Granite
LTW - Lightweight

Table 9

Slump Loss Tests

Mixture No. 38

W/C material: 0.30
S/A percent volume: 40
Cement/silica fume content, lb/yd^3: 799/141
WES 3/4 limestone aggregate
Rheobuild 561 HRWR at 30 fl oz./cwt materials.

Time, hours	Slump, in.
0	9
0.5	7-3/4
1.0	7-3/4
1.5	7-3/4
2.0	7-1/2
2.5	5-1/2

Mixture No. 48

W/C material: 0.24
S/A percent volume: 40
Cement/silica fume content lb/yd^3 each: 859/139
WES 3/4 limestone aggregate
W. R. Grace D-19 HRWR 1.0% by wt. cement materials.

Time, hours	Slump, in.
0	3-1/4
1	6
2	4

Mixture No. 58

W/C material: 0.24
S/A percent volume: 40
Cement/silica fume content, lb/yd^3 each: 799/141
WES 3/4 limestone coarse aggregate
W. R. Grace D-19 HRWR 1-1/4% by wt cement materials.

Time, hours	Slump, in.
0	8-1/2
1	8
2	4

Table 10

Compressive Strength Test Results

Mixture No.	W/C Ratio	Cement/Silica Fume/Fly Ash, lb/yd^3 each	Slump, in.	Compressive Strength, psi 7 days	14 days	28 days	90 days	Notes
1	0.27	940/0/0	1/2	6,350	7,350 (19 days)		8,820	
2	0.28	940/0/0	2-3/4	5,590	7,340 (19 days)	9,830	10,560	
3	0.30	940/0/0	2	7,670	6,780 (19 days)			
4	0.32	940/0/0	5-1/2	5,350		6,440 (19 days)	10,630	
5	0.32	940/0/0	6-1/2	4,890		6,270	6,170	
6	0.28	940/0/0	1	7,780		8,190 (18 days)	9,790	
7	0.30	799/141/0	6	6,300	9,527 (18 days)	11,650	12,790	
8	0.30	799/141/0	1-1/4	5,640		7,780 (18 days)	7,030	
9	0.28	799/141/0	6-1/2	7,670				
10	0.26	799/141/0	1-1/2	8,040			8,840 (175 days)	
11	0.30	799/141/0	6-3/4	8,560			11,950 (175 days)	
12	0.28	799/141/0	1				12,590 (175 days)	
13	0.28	799/141/0	2	8,830		12,410	12,170 (175 days)	
14	0.30	799/141/0	6	6,470	6,960		8,030 (174 days)	
15	0.24	859/139/0	9-1/2	10,840			15,420 (167 days)	

(Continued)

Table 10 (Continued)

Mixture No.	W/C Ratio	Cement/Silica Fume/Fly Ash, lb/yd^3 each	Slump, in.	Compressive Strength, psi				Notes
				7 days	14 days	28 days	90 days	
16	0.24	859/139/0	8	10,470		16,830	16,900 (167 days)	
17	0.24	859/139/0	2-1/2	11,600		16,660	18,100 (167 days)	
18	0.24	799/141/0	3-1/4	11,100		17,750	19,100 (167 days)	
19	0.26	799/141/0	9	12,940	13,470 (11 days)	15,910	18,670 (165 days)	
20	0.24	658/141/141	3-1/2	11,810	13,480 (11 days)	15,210	18,460 (165 days)	
21	0.24	799/141/0	3	11,650		14,820	15,700	
22	0.24	959/169/0	4-3/4	12,110		14,640	17,080	
23	0.22	959/169/0	3-1/2	12,025		13,970	17,580	
24	0.24	940/0/0	8	10,195		12,490	14,290	
25	0.22	940/0/0	3	11,795		11,920	14,470	
26	0.26	799/141/0	7	12,490		14,680	18,780 (153 days)	
27	0.24	799/141/0	3	10,315		14,460	17,440 (153 days)	
28	0.24	799/141/0	3	11,255		12,800	15,630 (152 days)	
29	0.24	799/0/141	3	10,110		12,990	15,810	Used Class "F" fly ash
30	0.24	799/0/141	2-1/2	9,760		11,180	13,580	Used Class "F" fly ash
31	0.24	902/226/0	2-3/4	10,930		14,290	17,330 (148 days)	
32	0.24	658/141/0	7	8,470		13,510	16,200 (148 days)	
33	0.24	658/141/141	3-1/2	9,740		14,290	16,370 (148 days)	Mix with silica fume and "F" fly ash
34	0.24	658/141/141	3-1/2	9,650		14,000	17,470 (148 days)	Mix with silica fume and "F" fly ash

(Continued)

Table 10 (Continued)

Mixture No.	W/C Ratio	Cement/Silica Fume/Fly Ash, lb/yd^3 each	Slump, in.	Compressive Strength, psi 7 days	14 days	28 days	90 days	Notes
35	0.24	959/169/0	8	10,120		16,300		
36	0.26	799/141/0	4	10,910		13,010	13,745	Harsh mix; 4 by 8 cylinders
37	0.24	658/141/141	6-1/2	11,050		13,390	16,130 (138 days)	
38	0.28	799/141/0	9	9,920		13,860	16,300 (116 days)	
39	0.28	799/141/0	6-3/4	9,600		12,450	14,400 (119 days)	5.3 percent air
40	0.30	799/141/0	8	8,550		11,560	12,200 (118 days)	7.4 percent air 12,660 @ 175 days
41	0.26	799/141/0	4	9,480		12,910	13,790 (118 days)	3.5 percent air 13,370 @ 175 days
42	0.24	799/141/0	1-3/4	11,410		16,175	17,620 (92 days)	17,540 @ 152 days
43	0.24	898/100/0	9	11,730		16,500	18,000 (95 days)	18,000 @ 152 days
44	0.24	799/141/0	3-1/2	9,370			17,760 (94 days)	17,270 @ 151 days
45	0.24	798/200/0	5	10,150			16,550 (94 days)	17,330 @ 151 days
46	0.30	799/141/0	8-/34	7,450			10,720	4-1/2 percent air 10,510 @ 147 days
47	0.24	859/139/0	10	11,365			16,300 (139 days)	2 percent high-range water reducer plus conventional water-reducing admixture
48	0.24	859/139/0	3-1/4	12,200			17,820	
49	0.24	859/139/0	1/4	12,695		16,270 (54 days)	18,000	Steel fibers at 200 lb/yd^3
50	0.24	799/0/141	8		9,900 (11 days)	13,830	15,990 (134 days)	Class "C" fly ash

(Continued)

Table 10 (Continued)

Mixture No.	W/C Ratio	Cement/Silica Fume/Fly Ash, lb/yd^3 each	Slump, in.	Compressive Strength, psi				Notes
				7 days	14 days	28 days	90 days	
51	0.24	752/0/188	9-1/4		10,650 (10 days)	14,610	15,420 (133 days)	Class "C" fly ash; too wet, segregated
52	0.24	658/0/282	8-1/4		10,700 (10 days)	14,460	16,910 (133 days)	Class "C" fly ash
53	0.42	798/200/0	10		2,350 (10 days)	3,490	4,530 (133 days)	
54	0.24	799/141/0	5-1/2		9,950 (10 days)	12,480	12,560 (114 days)	Chert gravel aggregate
55	0.24	658/141/141	8	11,600 (8 days)		16,400	18,420 (113 days)	
56	0.24	780/160/0		8,550		10,050	--	Mix with $CaCl_2$; see 24-hr test curve
57	0.24	780/160/0		7,500		8,220	--	Mix with $CaCl_2$; see 24-hr test curve
58	0.24	799/141/0	8-1/2			17,890 (42 days)	19,380 (108 days)	20,760 psi at 164 days, on a 4 by 8 cylinder
59	0.24	859/139/0	1/4	10,400			16,200 (107 days)	Repeat of mix 16 with fiberglass reinforcement
60	0.24	859/139/0	1/2	10,900			17,050 (107 days)	Repeat of mix 16 with fiberglass reinforcement
61	0.24	859/139/0	1/2	9,100			13,760 (106 days)	Repeat of mix 16 with polypropylene fibers
62								Not cast

(Continued)

Table 10 (Concluded)

Mixture No.	W/C Ratio	Cement/Silica Fume/Fly Ash lb/yd^3 each	Slump, in.	Compressive Strength, psi				Notes
				7 days	14 days	28 days	90 days	
63								Not cast
64	0.24	799/141/0	8-1/2	10,400		14,260 (35 days)	16,020 (105 days)	Air = 4.6 percent; cast three freeze-thaw beams
65	0.24	799/141/0	9-1/4	11,600		16,440 (35 days)	18,960 (158 days)	Air = 1.0 percent; cast three freeze-thaw beams
66	0.24	799/141/0	8-1/2			14,220 (32 days)	14,710 (155 days)	Air = 4.0 percent; cast three freeze-thaw beams
67	0.24	799/141/0	8-1/2			13,350 (31 days)	16,840 (154 days)	Air = 5.8 percent; cast three freeze-thaw beams
68	0.24	799/141/0	9			16,590 (31 days)	18,390 (154 days)	Air = 0.8 percent; cast three freeze-thaw beams
69	0.24	846/94/0				16,270 (34 days)	15,100 (100 days)	
70	0.24	799/141/0	2			5,530 (20 days)	8,420 (82 days)	Lightweight aggregate mixture; very harsh
71	0.24	879/155/0	10-1/2			7,590 (19 days)	7,790 (83 days)	Lightweight mix; worked better than No. 71; density 116.9 lb/ft^3
72	0.22	959/169/0	11			7,120 (18 days)	8,300 (84 days)	Density 121.2 lb/ft^3
73	0.24	959/169/0				14.060 (17 days)	15,400 (102 days)	Repeat of mix 22
74	0.24	959/01169				10,540 (17 days)	12,930 (102 days)	Repeat of mix 22 without silica fume
75	0.24	959/169/0					14,140 (102 days)	Repeat of mix 35
76	0.24	959/01169					11,920 (102 days)	Repeat of mix 35 without silica fume

Note: Strength data for mixes 73-76 are from 4 by 8 cylinders.

Table 11

Mixtures with Project Limestone Coarse Aggregate

No. Batch	W/C	Cement/ Silica Fume/ Fly Ash, lb/yd^3	HRWR % of Cmt Mtls	Slump, in.	Compressive Strength, psi, at Days 6-7	14	28	90+
1	0.27	940/0/0	0.5	1/2	6,350	7350		8,820
2	0.28	940/0/0	0.5	2-3/4	5,590	7340	9,830	10,560
3	0.30	940/0/0	0.5	2	7,670	6780		
4	0.32	940/0/0	0.5	5-1/2	5,350	6440		10,630
5	0.32	940/0/0	0.5	6-1/2	4,890		6,270	6,170
7	0.30	799/141/0	0.8	6	6,300	9527	11,650	12,790
12	0.28	799/141/0	0.8	1				12,590
13	0.28	799/141/0	0.8	2	8,830		12,410	12,170
14	0.30	799/141/0	0.8	6	6,470	6960		8,030
21	0.24	799/141/0	1.0	3	11,650		14,820	15,700
22	0.24	959/169/0	1.0	7-3/4	12,110		14,640	17,080
23	0.22	959/169/0	1.0	3-1/2	12,025		13,970	17,580
28	0.24	799/141/0	1.0	3	11,255		12,800	15,630
30	0.24	799/0/141	1.0	2-1/2	9,760		11,180	13,580
32	0.24	658/141/0	1.0	7	8,470		13,510	16,200
33	0.24	658/141/141	1.0	3-1/2	9,740		14,290	16,130
37	0.24	658/141/141	1.0	6-1/2	11,050		13,390	16,130
66	0.24	799/141/0	1.25	8-1/2			14,220	14,710
69	0.24	846/94/0	1.25				16,270	15,100
73	0.24	959/169/0	1.0			14060		15,400
74	0.24	1143/0/0	1.0			10540		12,930

Table 12

Mixtures witn Project Granite Coarse Aggregate

No. Batch	W/C	Cement/ Silica Fume/ Fly Ash, lb/yd^3	HRWR % of Cmt Mtls	Slump, in.	Compressive Strength, psi, at Days 6-7	14	28	90+
24	0.24	940/0/0	1.00	8	10,195		12,490	14,290
25	0.22	940/0/0	1.00	3	11,795		11,920	14,470
26	0.24	799/141/0	1.00	3-1/2	12,490		14,680	18,780
27	0.26	799/141/0	1.00	7	10,315		14,460	17,440
29	0.24	799/0/141	1.00	3	10,110		12,990	15,810
31	0.20	902/226/0	1.00	2-3/4	10,930		14,290	17,330
34	0.24	658/141/141	1.00	3-1/2	9,650		14,000	17,470
35	0.24	959/169/0	1.00	8	10,120		16,300	16,090
36	0.26	799/141/0	1.00	7	10,910		13,010	13,745
67	0.24	799/141/0	1.25	8-1/2			13,350	16,840
68	0.24	799/141/0	1.25	9			16,590	18,390
75	0.24	959/169/0	1.00	8				14,140
76	0.24	1128/0/0	1.00	8				

Table 13

ELASTIC PROPERTY RESULTS

Mixture No.	Young's Modulus psi x 10^6	Poisson's Ratio ν	Compressive Strength 28 Days psi	Split Tensile Strength psi %
38	6.40	-	13,860	-
39	6.49	-	12,450	-
40	6.36	-	11,560	-
41	6.15	-	12,910	-
64	6.64	0.242	14,260 (35 days)	1140 (31 days)
65	6.68	0.256	16,440 (35 days)	1260 (31 days)
66	6.78	0.230	14,220 (32 days)	1180 (29 days)
67	5.91	0.208	13,350 (31 days)	1220 (28 days)
68	6.25	0.216	16,590 (31 days)	1440 (28 days)
72	3.70	0.210	7,120 (18 days)	

WES Form 2075
Jan 75

Table 14

EXPANSION DATA SHEET

Lab XX Field ___ Page ___ of ___ Pages

PROJECT: HIGH STRENGTH CONCRETE

MIX DESIGN: NO. 22 WITHOUT SILICA FUME

DATE CAST: 30 SEP 83

DATE DEMOLDED: 1 OCT 83 at 24 HRS Age

Source Of Data: LABORATORY

ASTM C 490 & ASTM C 157

MATERIAL FOR 1-IN. PRISMS PASSED THE NO. 4 SIEVE.

Remarks: CONTROL MIXTURE

TYPE II CEMENT 1128.0 LBS/YD^3

WATER 270.0 LBS/YD^3

W/C 0.24

		1-IN. UNRESTRAINED					3-IN. UNRESTRAINED				
DATE	AGE (DAYS)	BAR 1	% EXP	BAR 2	% EXP	AVERAGE	BAR 1	% EXP	BAR 2	% EXP	AVERAGE
Oct 1	INITIAL	0.2643	----	0.2068	----	----	0.1295	----	0.1161	----	----
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	10										
	11										
	12										
	13										
Oct 14	14	0.2654	0.011	0.2079	0.011	0.011	0.1297	0.002	0.1161	0.000	0.001
	21										
Oct 28	28	0.2656	0.013	0.2081	0.013	0.013	0.1294	-0.001	0.1159	-0.002	-0.002
Jan 10	101	0.2670	0.027	0.2094	0.027	0.027	0.1304	0.009	0.1171	0.010	0.010

WES Form 2976
Jan 75

Table 15

EXPANSION DATA SHEET

Lab XX Field ___ Page ___ of ___ Pages

PROJECT: HIGH STRENGTH CONCRETE

DATE CAST: 30 SEP 83

MIX DESIGN: NO. 22 WITH SILICA FUME

DATE DEMOLDED: 1 OCT 83 at 24 HRS Age

Source Of Data: LABORATORY

ASTM C 490 & ASTM C 157

MATERIAL FOR 1-IN. PRISMS PASSED THE NO. 4 SIEVE.

Remarks: TEST MIXTURE

TYPE II CEMENT	958.8	LBS/YD^3
SILICA FUME	169.2	LBS/YD^3
WATER	270.7	LBS/YD^3
W/C	0.24	

		1-IN. UNRESTRAINED					3-IN. UNRESTRAINED				
DATE	AGE (DAYS)	BAR 1	% EXP	BAR 2	% EXP	AVERAGE	BAR 1	% EXP	BAR 2	% EXP	AVERAGE
Oct 1	INITIAL	0.2574	----	0.2408	----	----	0.1304	----	0.1323	----	----
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	10										
	11										
	12										
	13										
Oct 14	14	0.2574	0.000	0.2408	0.000	0.000	0.1297	-0.007	0.1315	-0.008	-0.008
	21										
Oct 28	28	0.2573	-0.001	0.2407	-0.001	-0.001	0.1293	-0.011	0.1311	-0.012	-0.012
Jan 10	101	0.2580	0.006	0.2414	0.006	0.006	0.1301	-0.003	0.1317	-0.006	-0.005

WES Form 1076
Jan 75

Table 16

EXPANSION DATA SHEET

Lab XX Field ___ Page ___ of ___ Pages

PROJECT: HIGH STRENGTH CONCRETE

DATE CAST: 30 SEP 83

MIX DESIGN: NO. 35 WITHOUT SILICA FUME

DATE DEMOLDED: 1 OCT 83 at 24 HRS Age

Source Of Data: LABORATORY
ASTM C 490 & ASTM C 157
MATERIAL FOR 1-IN. PRISMS PASSED THE NO. 4 SIEVE.

Remarks: CONTROL MIXTURE
TYPE II CEMENT 1128.0 LBS/YD^3
WATER 270.7 LBS/YD^3
W/C 0.24

		1-IN. UNRESTRAINED					3-IN. UNRESTRAINED				
DATE	AGE (DAYS)	BAR 1	% EXP	BAR 2	% EXP	AVERAGE	BAR 1	% EXP	BAR 2	% EXP	AVERAGE
Oct 1	INITIAL	0.1420	----	0.1253	----	-----	0.1381	----	0.1344	----	----
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	10										
	11										
	12										
	13										
Oct 14	14	0.1431	0.011	0.1263	0.010	0.011	0.1380	-0.001	0.1344	0.000	-0.001
	21										
Oct 28	28	0.1431	0.011	0.1266	0.013	0.012	0.1377	-0.004	0.1341	-0.003	-0.004
Jan 10	101	0.1444	0.024	0.1279	0.026	0.025	0.1389	0.008	0.1352	0.008	0.008

WES Form 2076
Jan 75

Table 17

EXPANSION DATA SHEET

Lab XX Field ___ Page ___ of ___ Pages

PROJECT: HIGH STRENGTH CONCRETE

MIX DESIGN: NO. 35 WITH SILICA FUME

DATE CAST: 30 SEP 83

DATE DEMOLDED: 1 OCT 83 at 24 HRS Age

Source Of Data: LABORATORY

ASTM C 490 & ASTM C 157

MATERIAL FOR 1-IN. PRISMS PASSED THE NO. 4 SIEVE

Remarks: TEST MIXTURE

TYPE II CEMENT	958.8 LBS/YD^3
SILICA FUME	169.2 LBS/YD^3
WATER	270.0 LBS/YD^3
W/C	0.24

		1-IN. UNRESTRAINED					3-IN. UNRESTRAINED				
DATE	AGE (DAYS)	BAR 1	% EXP	BAR 2	% EXP	AVERAGE	BAR 1	% EXP	BAR 2	% EXP	AVERAGE
Oct 1	INITIAL	0.2658	----	0.3052	----	----	0.1318	----	0.1300	----	----
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	10										
	11										
	12										
	13										
Oct 14	14	0.2658	0.000	0.3049	-0.003	-0.002	0.1312	-0.006	0.1293	-0.007	-0.007
	21										
Oct 28	28	0.2657	-0.001	0.3047	-0.005	-0.003	0.1309	-0.009	0.1290	-0.010	-0.010
Jan 10	101	0.2664	0.006	0.3055	0.003	0.005	0.1316	-0.002	0.1297	-0.003	-0.003

Table 18

DATA SHEET FOR HARDENED CONCRETE SPECIMENS
(CRD-C 13, 25, 40, 47, 114, 38, 36,37, 35,124)

SYMBOL: JOB NO: 441-S591 MEMO NO: DATE: 8-5-83 INITIALS: DMW

PROJECT: HIGH STR. SPECIMEN TYPE: 3-1/2 X 9-1/2 x 16 in. FIELD: ☐ LAB: ☐.

DATE PLACED: 8/8/83 DATE CORED: CURING: TYPE: Inundated Fot Room DURATION: 28 D

FINE AGG: Limestone OM 19 S-1 COARSE AGG: Limestone OM 19 G-2 MAX. 1 IN.

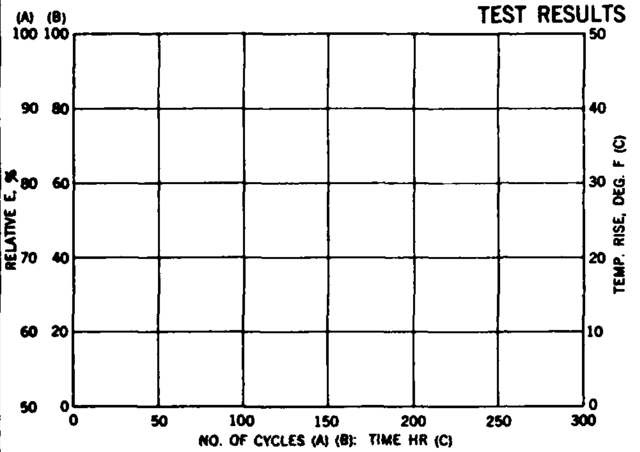
CEMENT RC (894(1) TH. C.F. B/CY. ACT. C.F. B/CY: 940 cmt+silfume S/A % VOL: 40

AIR % TOTAL: 4.0 IN-1 1/2: W/C GPB 0.24 SLUMP IN. (-1 1/2): 8-1/2

TH. U.W. LB/CU. FT: ACT. U.W. (PLASTIC): ADMIX:

TESTS:	F & T BEAMS C 114 ☐ C 13 ☐	F & T 10" CORES C 47 ☐	SPEC. HEAT C 35, 124 ☐	HWCD C 40 ☐	HDCW C 40 ☐	SHRINKAGE C 25 ☐	HEAT RISE C 38 ☐	DIFFUSIV. C 36, 7 ☐	OTHER ☐ SEE REMARKS
BEGIN DATE:									
SPEC. NO.	97-81 97-82 97-83								

TEST RESULTS



SPEC. NO.	SYMBOL	DFE	NO. CYCLES E-50	NO. CYCLES TOTAL	INIT. FREQ.	REMARKS

SPEC. NO.	HEAT RISE, F 7 D	HEAT RISE, F 14 D	DIFF, FT^2/HR	SPEC. HEAT	REMARKS

DENSITY (HARDENED) LB/CU. FT:

INITIALS:

(A) FOR 3 1/2 X 4 1/2 X 16-IN BEAMS
(B) FOR CORE SPECIMENS
(C) FOR TEMPERATURE RISE

LAB TRIAL MIXT NO. 66 (TEST MIXT: NO CONTROL)

SPEC. NO.	RELATIVE E AT NO. OF CYCLES SHOWN							
Cycles	0	47	93	152	210	256	294	356
9781	100	96	95	96	95	93	86	71
9782	100	96	96	96	95	93	77	74
9783	100	97	96	97	94	91	93	60

DATE TEST COMPLETED:

INITIALS:

REPORT OF EXAMINATION AFTER TEST

Relative E at No. of Cycles Shown

Cycles	380	430
9781	64	45
9782	43	49
9783	48	--

DATE: INITIALS:

REMARKS:

W. R. Grace HRWR DAXAD 19 (dry) 1-1/4% by wt cmt mtls (cmt+fume)
AEA AMEX 210 6 fl oz per cwt cmt mtls (cmt+fume)

WES FORM 534
REV. MAR. 50

Table 19

DATA SHEET FOR HARDENED CONCRETE SPECIMENS
(CRD-C 13, 25, 40, 47, 114, 38, 36,37, 35,124)

SYMBOL: JOB NO: 441-S592 MEMO NO: DATE: 8-9-83 INITIALS: DMW

PROJECT: HIGH STR. CONC SPECIMEN TYPE: 3-1/2 x 4-1/2 x 16 in. FIELD: LAB: B.

DATE PLACED: 8/9/83 DATE CORED: CURING: TYPE: Inundated Fog Room DURATION: 28 D

FINE AGG: Limestone OM 19 S-1 COARSE AGG: Granite OM 19 G-1 MAX. 1-1/2 IN.

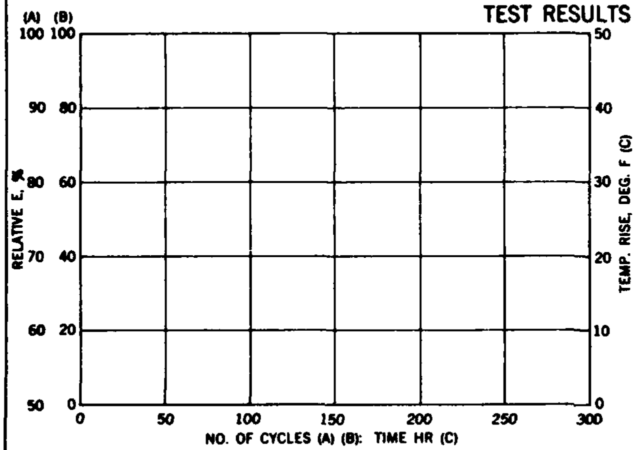
CEMENT: RC 894 (2) TH. C.F. B/CY: ACT. C.F. B/CY: 940 cmt+silfume S/A % VOL: 40

AIR % TOTAL: 5.8 IN-1 1/2: W/C GPB 0.24 SLUMP IN. (-1 1/2): 8-1/2

TH. U.W. LB/CU. FT: ACT. U.W. (PLASTIC): ADMIX:

TESTS:	F & T BEAMS C 114 ☐ C 13 ☐	F & T 10" CORES C 47 ☐	SPEC. HEAT C 35, 124 ☐	HWCD C 40 ☐	HDCW C 40 ☐	SHRINKAGE C 25 ☐	HEAT RISE C 38 ☐	DIFFUSIV. C 36, 7 ☐	OTHER ☐ SEE REMARKS
BEGIN DATE:									
SPEC. NO.	97-84 97-85 97-86								

TEST RESULTS



SPEC. NO.	SYMBOL	DFE	NO. CYCLES E=50	NO. CYCLES TOTAL	INIT. FREQ.	REMARKS

SPEC. NO.	HEAT RISE, F 7 D	HEAT RISE, F 14 D	DIFF, FT^2/HR	SPEC. HEAT	REMARKS

DENSITY (HARDENED) LB/CU. FT:

INITIALS:

(A) FOR 3 1/2 X 4 1/2 X 16-IN BEAMS
(B) FOR CORE SPECIMENS
(C) FOR TEMPERATURE RISE

LAB TRIAL MIXT NO. 67 (TEST MIXT)

SPEC. NO.	RELATIVE E AT NO. OF CYCLES SHOWN							
Cycles	0	58	119	165	200	246	307	346
9784	100	99	97	97	96	96	88	81
9785	100	97	97	97	97	96	90	82
9786	100	97	96	96	96	95	95	94

DATE TEST COMPLETED:

INITIALS:

REPORT OF EXAMINATION AFTER TEST

Relative E at No. of Cycles Shown

Cycles	395	437
9784	77	31
9785	79	29
9786	93	27

DATE: INITIALS:

REMARKS:

W. R. Grace HRWR DAX49-19(dry) 1-1/4% by wt cmt mtls (cmt+fume)
AEA AMEX 210 8 fl oz per cwt cmt mtls (cmt+sil fume)

WES FORM 534
REV. MAR. 50

Table 20

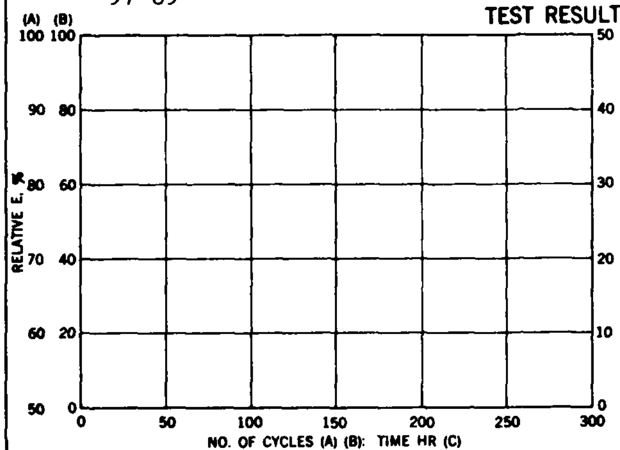
DATA SHEET FOR HARDENED CONCRETE SPECIMENS

(CRD-C 13, 25, 40, 47, 114, 38, 36,37, 35,124)

SYMBOL:	JOB NO: 441-S592	MEMO NO:	DATE: 8-9-83	INITIALS: DMW	
PROJECT: HIGH STR CONC		SPECIMEN TYPE: 3-1/2 x 4-1/2 x 16 in		FIELD: ☐ LAB: ☒	
DATE PLACED: 8/9/83	DATE CORED:	CURING: TYPE: Inundated Fog Room		DURATION: 28 D	
FINE AGG: Limestone OM 19 S-1		COARSE AGG: Granite 19 G-1		MAX. 1-1/2 IN.	
CEMENT RC 894(2)	TH. C.F. B/CY:	ACT. C.F. B/CY: 940 cmt+silfume		S/A % VOL: 40	
AIR % TOTAL: 0.8	IN-1 1/2:	W/C GPB 0.24		SLUMP IN. (-1 1/2): 9	
TH. U.W. LB/CU. FT:		ACT. U.W. (PLASTIC):		ADMIX:	

TESTS:	F & T BEAMS C 114 ☐ C 13 ☐	F & T 10" CORES C 47 ☐	SPEC. HEAT C 35, 124 ☐	HWCD C 40 ☐	HDCW C 40 ☐	SHRINKAGE C 25 ☐	HEAT RISE C 38 ☐	DIFFUSIV. C 36, 7 ☐	OTHER ☐ SEE REMARKS
BEGIN DATE:									
SPEC. NO.	97-87 97-88 97-89								

TEST RESULTS



SPEC.-NO.	SYMBOL	DFE	NO. CYCLES E=50	NO. CYCLES TOTAL	INIT. FREQ.	REM-ARKS

SPEC. NO.	HEAT RISE, F 7 D	HEAT RISE, F 14 D	DIFF, FT^2/HR	SPEC. HEAT	REMARKS

DENSITY (HARDENED) LB/CU. FT: ________

INITIALS: ________

(A) FOR 3 1/2 X 4 1/2 X 16-IN BEAMS
(B) FOR CORE SPECIMENS
(C) FOR TEMPERATURE RISE

LAB MIXT NO. 68 (CONTROL MIXT FOR NO. 67)

SPEC. NO.	RELATIVE E AT NO. OF CYCLES SHOWN							
Cycles	0	58	119	165	200	246	307	346
9887	100	99	99	99	98	97	96	93
9888	100	96	98	98	98	97	96	95
9889	100	97	96	96	96	96	91	80

DATE TEST COMPLETED: ________

INITIALS: ________

REPORT OF EXAMINATION AFTER TEST

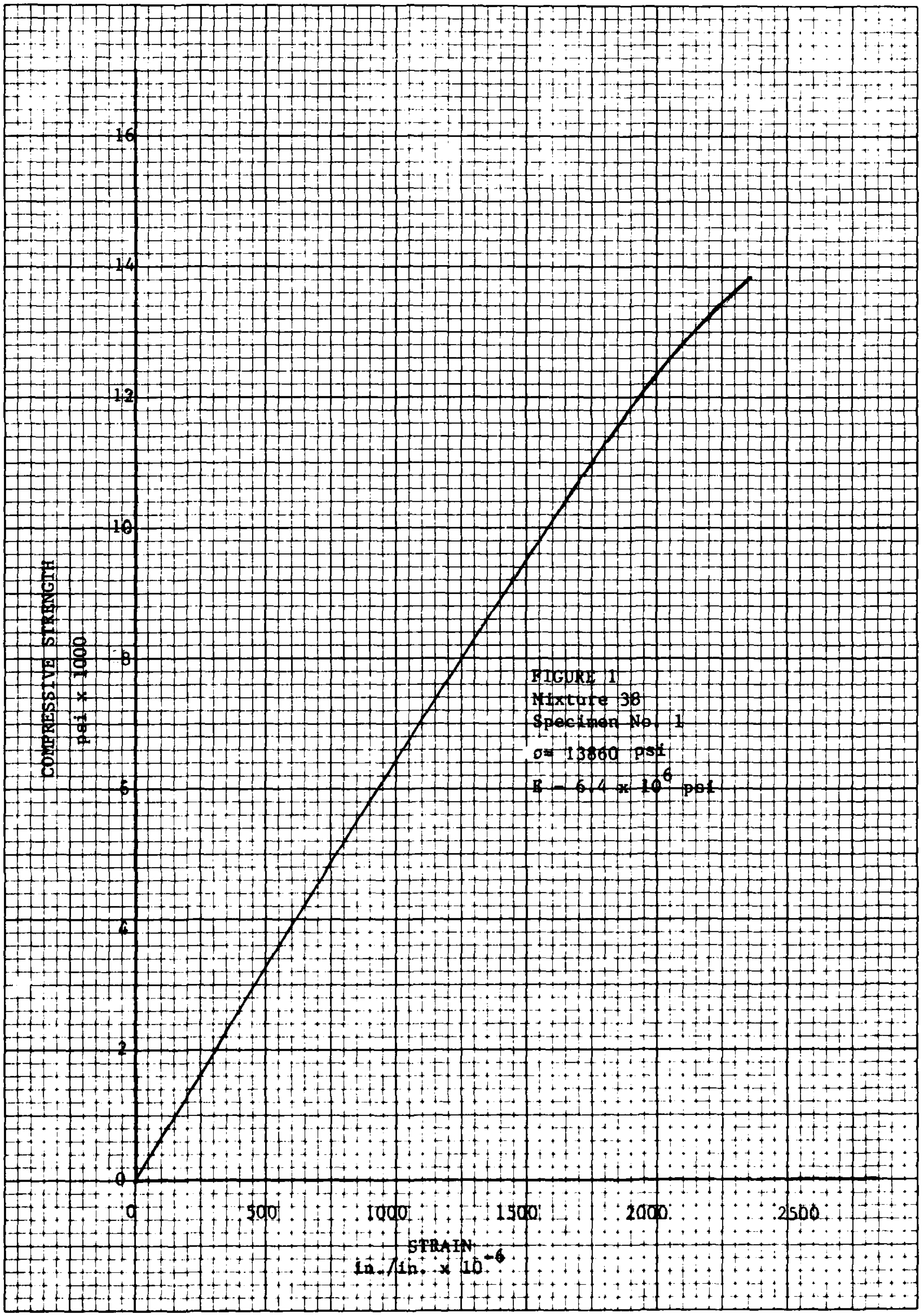
Relative E at No. of Cycles Shown

Cycles	395	437
9887	83	31
9888	85	30
9889	72	26

DATE: INITIALS:

REMARKS:
W. R. Grace HRWR DAXAD-19 (dry) 1-1/4% by wt cmt mtls (cmt + fume)
Control Mixture - No AEA used - the 0.8% is entrapped air.

WES FORM 534
REV. MAR. 50


COMPRESSIVE STRENGTH
psi x 1000
0
2
4
6
8
10
12
14
16
0
500
1000
1500
2000
2500
STRAIN
in./in. x 10^{-6}
FIGURE 1
Mixture 38
Specimen No. 1
σ= 13860 psi
E = 6.4 x 10^{6} psi

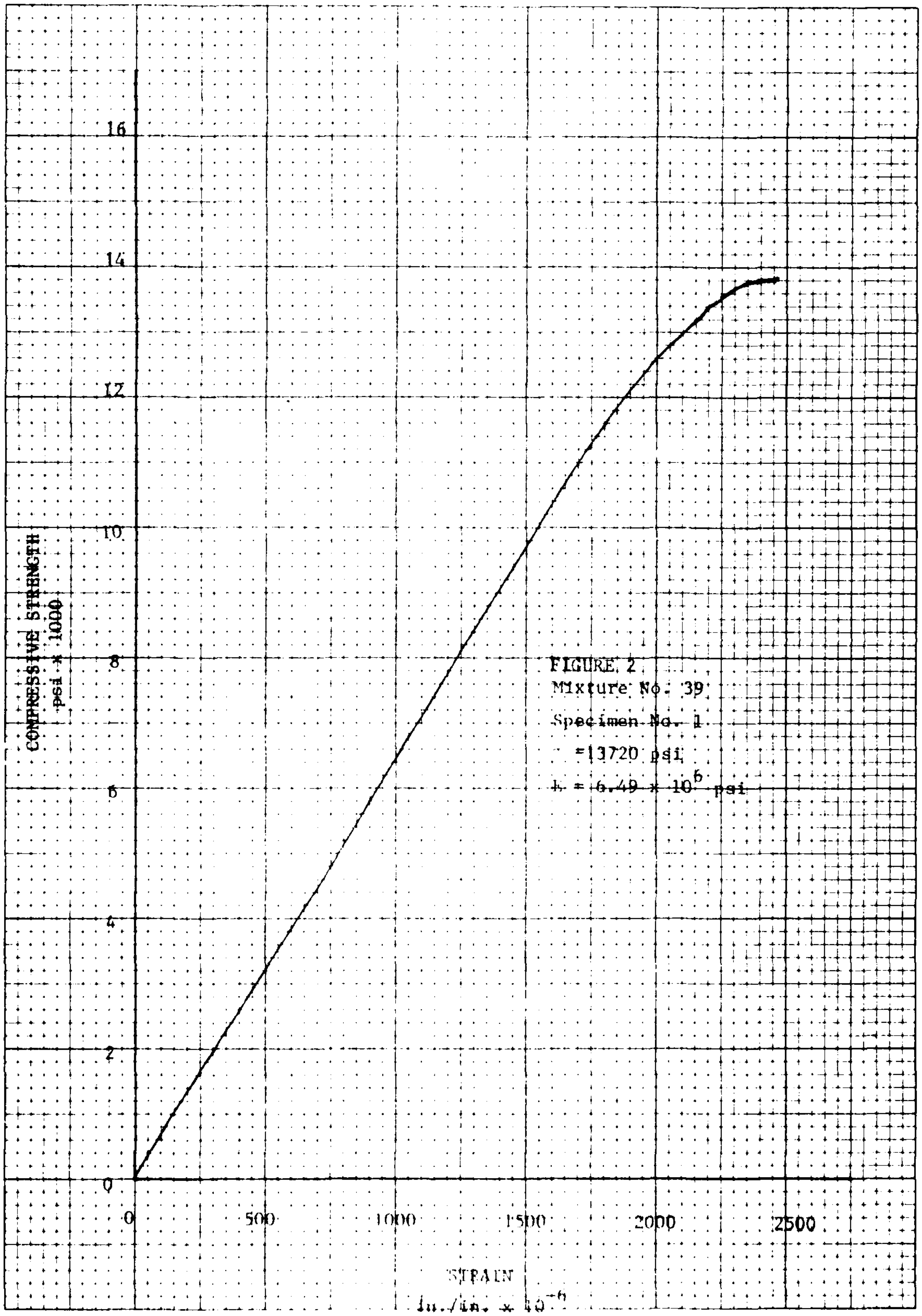


FIGURE 2
Mixture No. 39
Specimen No. 1
=13720 psi
E = 6.49 x 10^6 psi

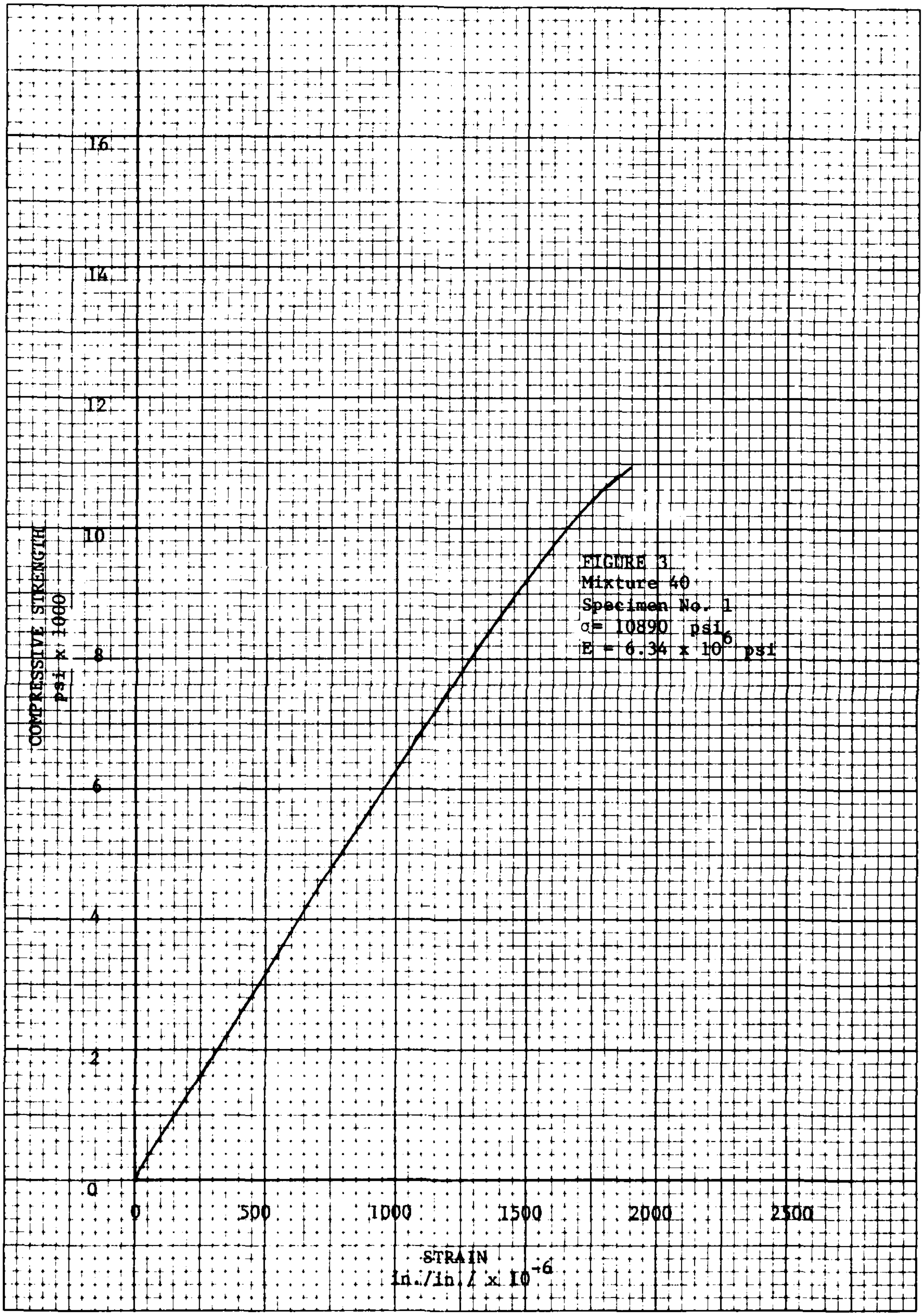
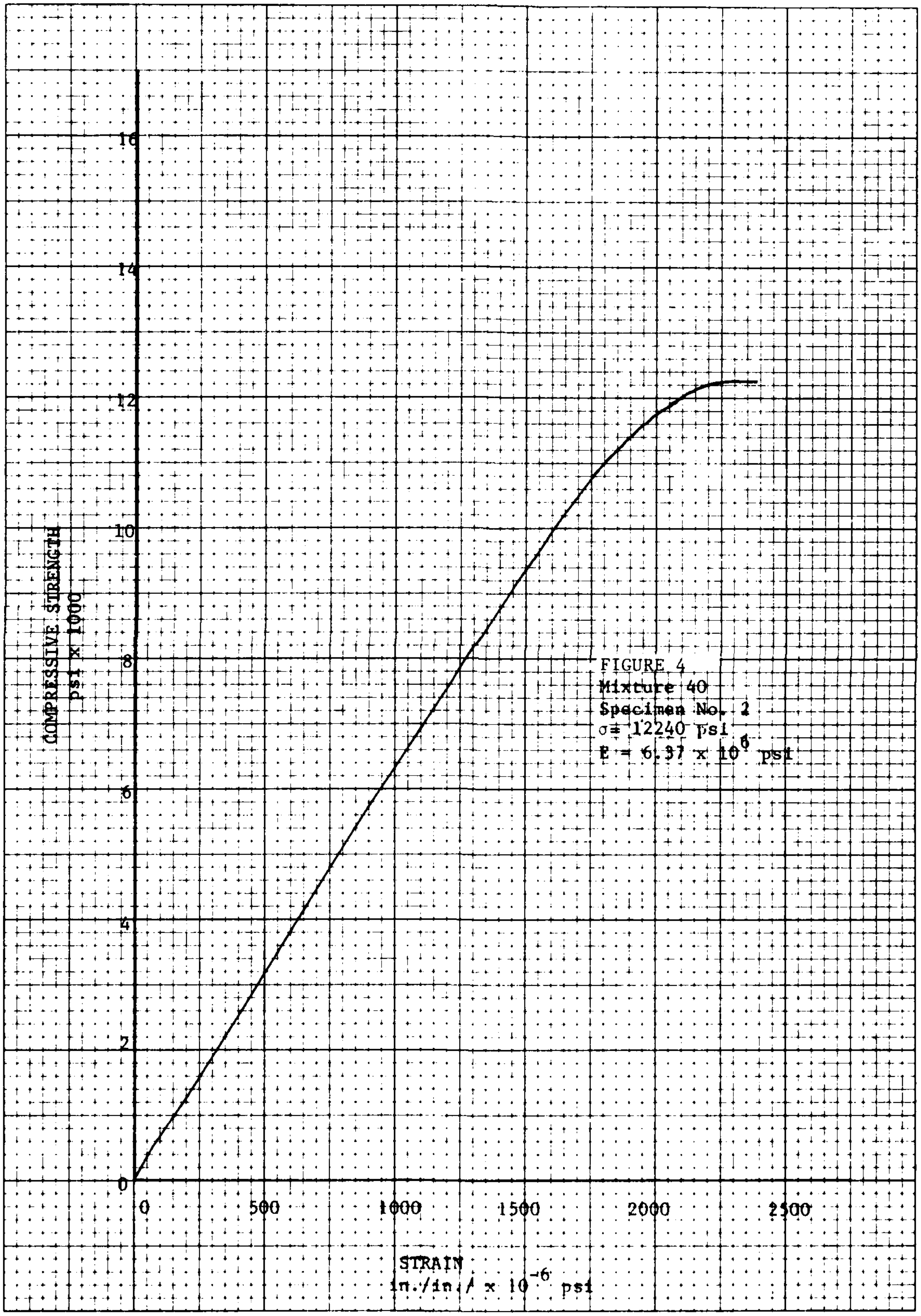
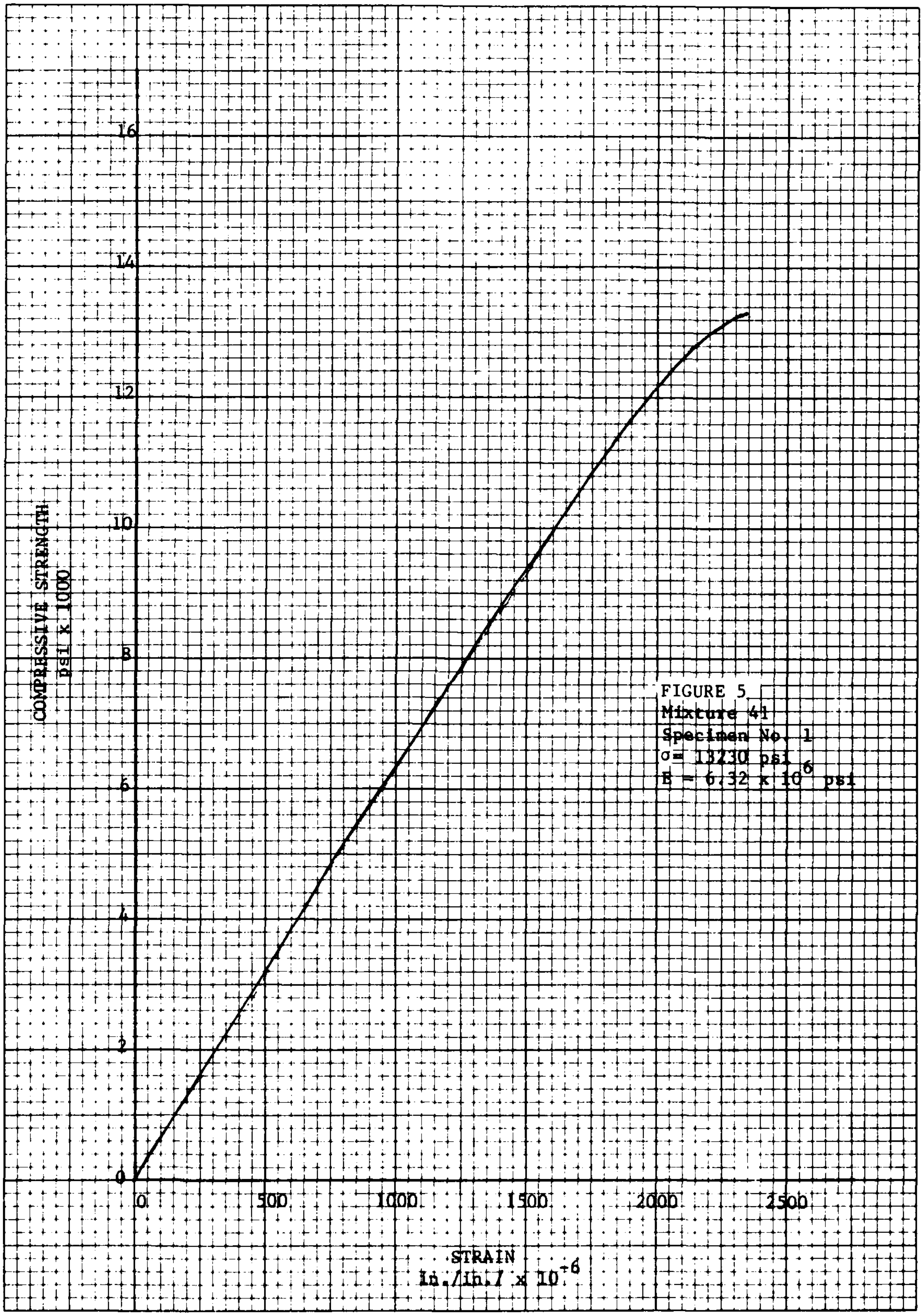
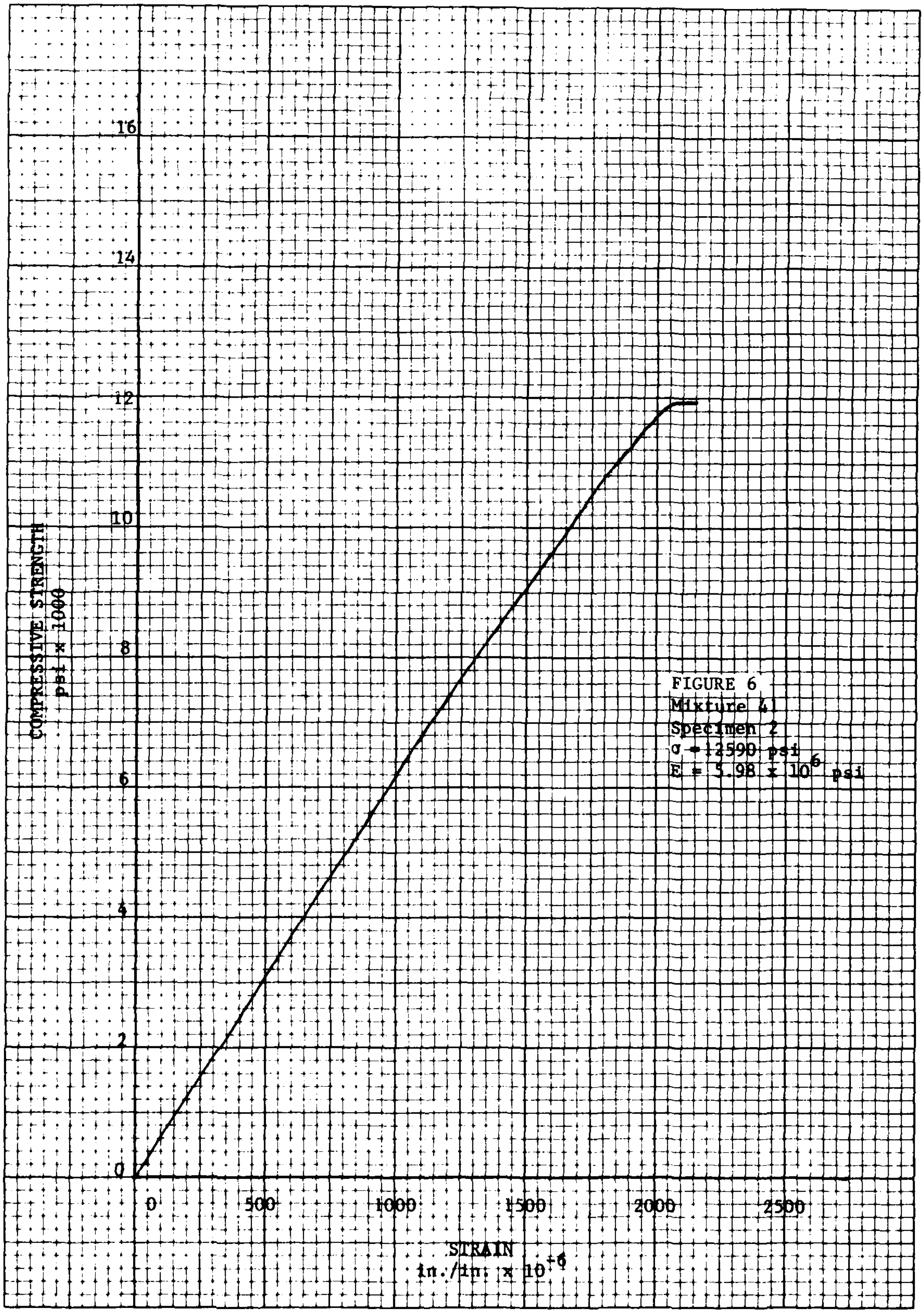


FIGURE 3
Mixture 40
Specimen No. 1
$\sigma = 10890$ psi
$E = 6.34 \times 10^{6}$ psi

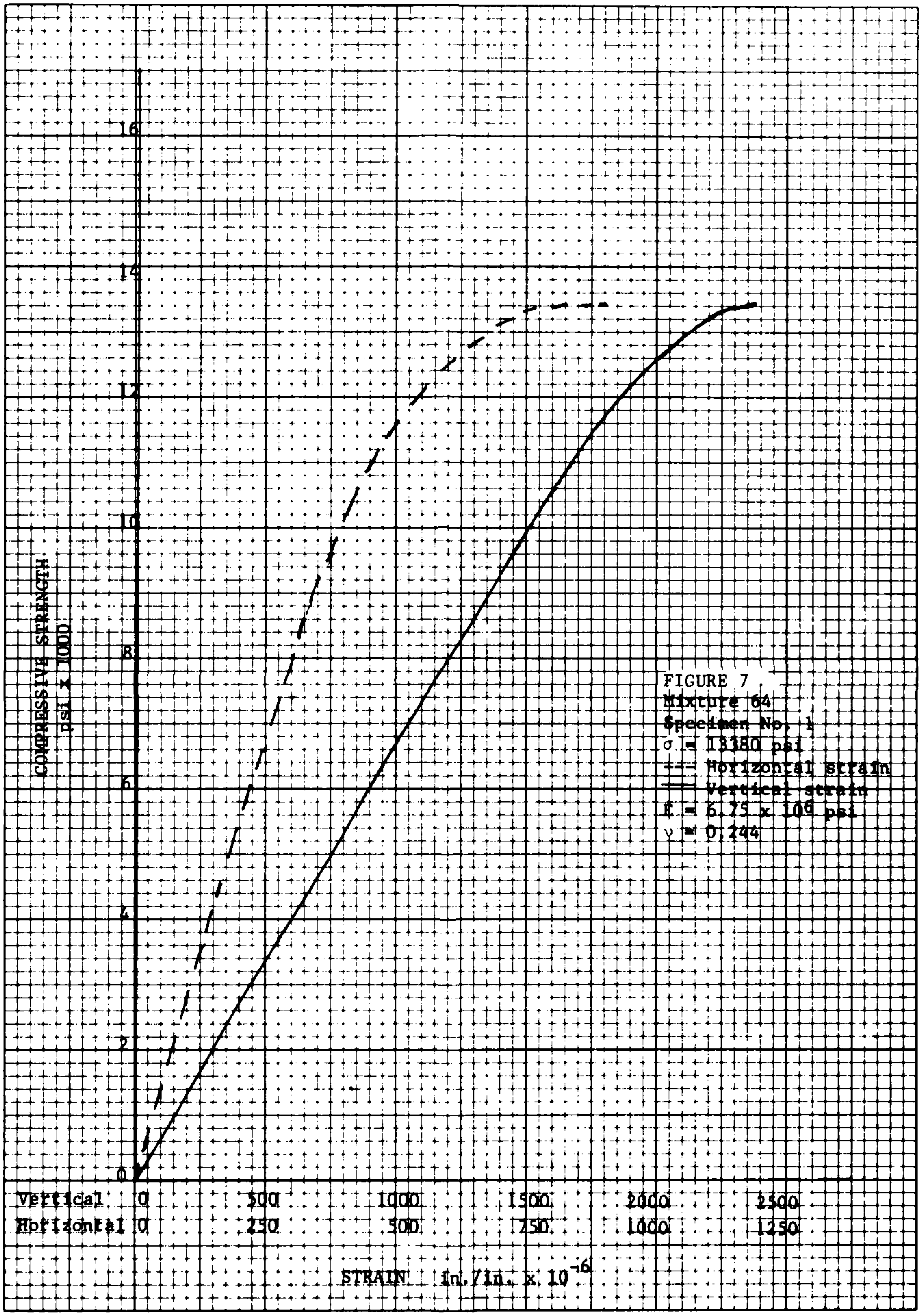


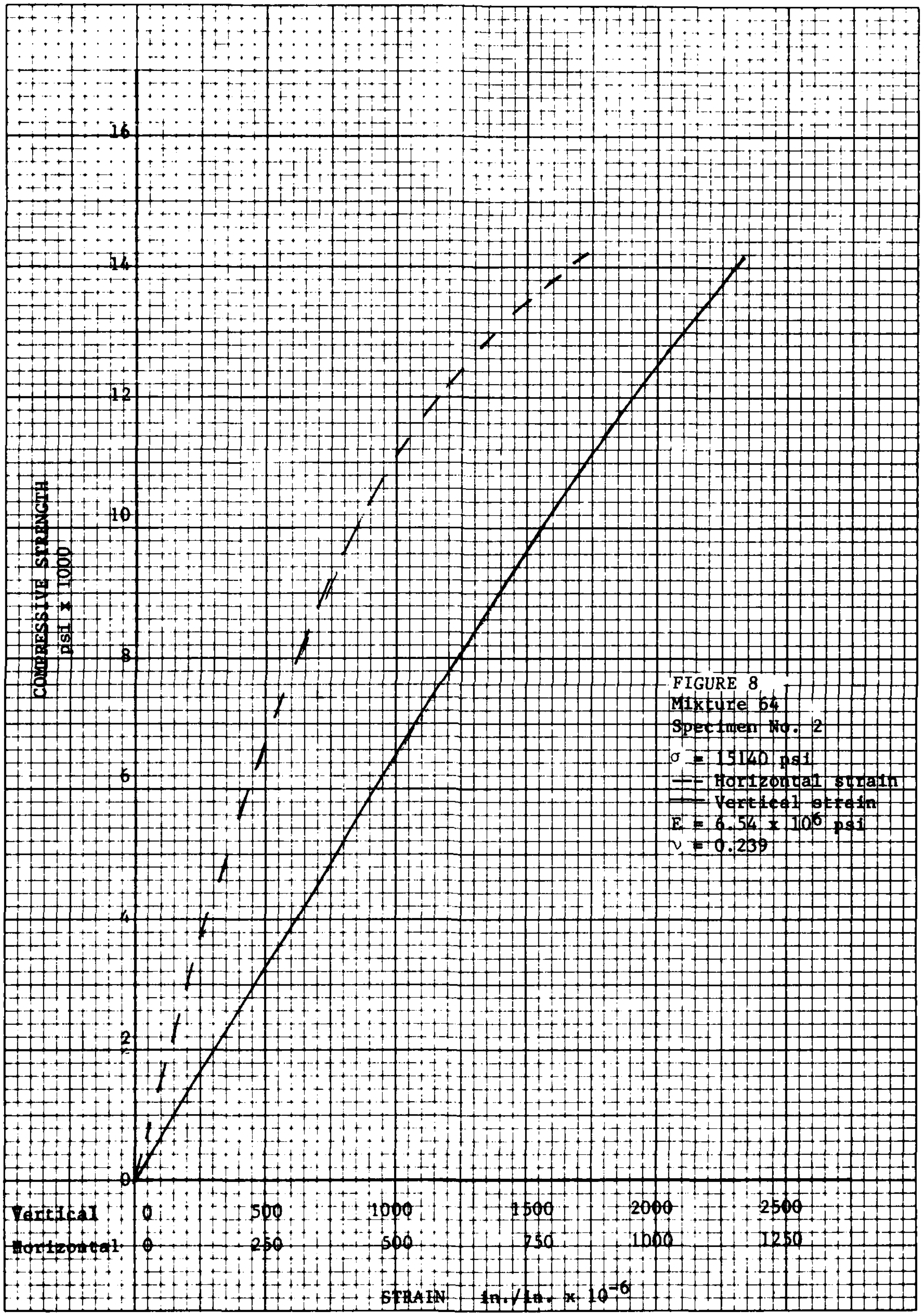
COMPRESSIVE STRENGTH
psi x 1000
16
14
12
10
8
6
4
2
0
0
500
1000
1500
2000
2500
STRAIN
in./in./ x 10^-6 psi
FIGURE 4
Mixture 40
Specimen No. 2
σ= 12240 psi
E = 6.37 x 10^6 psi


COMPRESSIVE STRENGTH
psi x 1000
0
2
4
6
8
10
12
14
16
0
500
1000
1500
2000
2500
STRAIN
In./In./ x 10^{-6}
FIGURE 5
Mixture 41
Specimen No. 1
σ= 13230 psi
E = 6.32 x 10^{6} psi

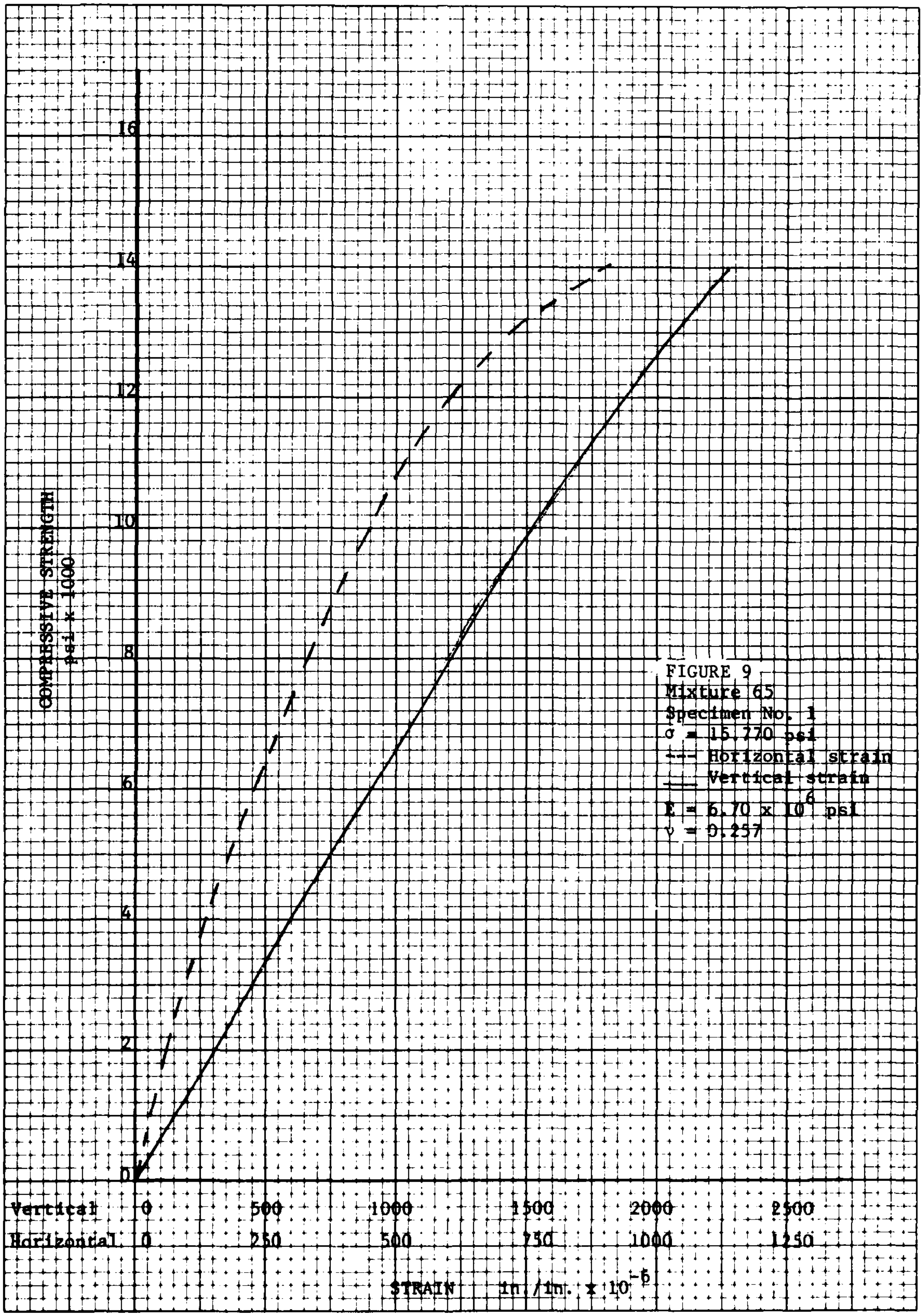


NO. 340-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH
EUGENE DIETZGEN CO.
MADE IN U. S. A.


16
14
12
10
8
6
4
2
0
COMPRESSIVE STRENGTH
psi X 1000
Vertical 0 500 1000 1500 2000 2500
Horizontal 0 250 500 750 1000 1250
STRAIN in./in. x 10^{-6}
FIGURE 7
Mixture 64
Specimen No. 1
σ = 13380 psi
--- Horizontal strain
— Vertical strain
E = 6.75 x 10^6 psi
ν = 0.244



COMPRESSIVE STRENGTH
psi x 1000
0
2
4
6
8
10
12
14
16
Vertical 0 500 1000 1500 2000 2500
Horizontal 0 250 500 750 1000 1250
STRAIN in./in. x 10^{-6}
FIGURE 8
Mixture 64
Specimen No. 2
σ = 15140 psi
Horizontal strain
Vertical strain
E = 6.54×10^6 psi
ν = 0.239



COMPRESSIVE STRENGTH
psi x 1000
16
14
12
10
8
6
4
2
0
Vertical 0 500 1000 1500 2000 2500
Horizontal 0 250 500 750 1000 1250
STRAIN in./in. x 10^-6
FIGURE 9
Mixture 65
Specimen No. 1
σ = 15,770 psi
--- Horizontal strain
___ Vertical strain
E = 6.70 x 10^6 psi
ν = 0.257

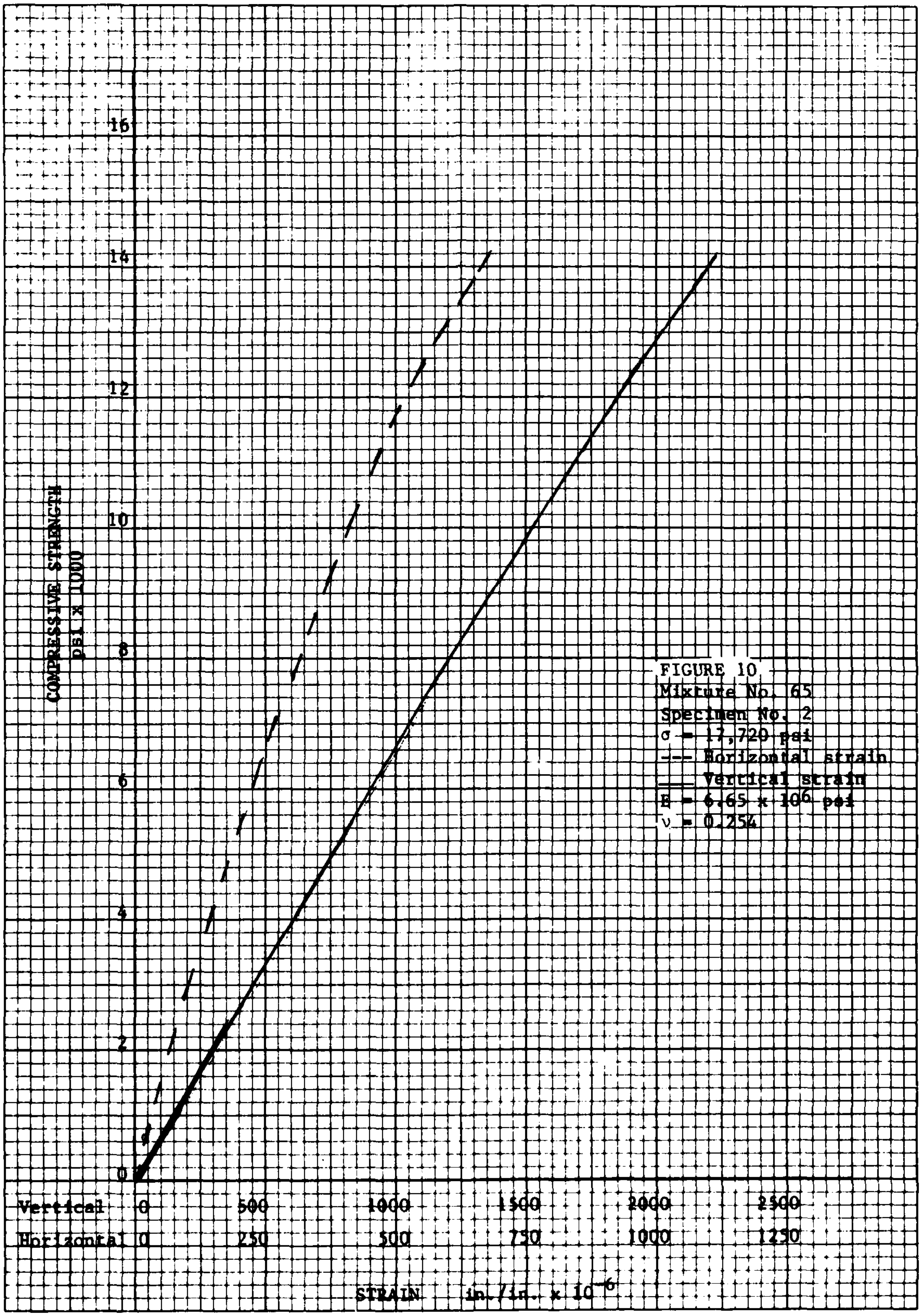
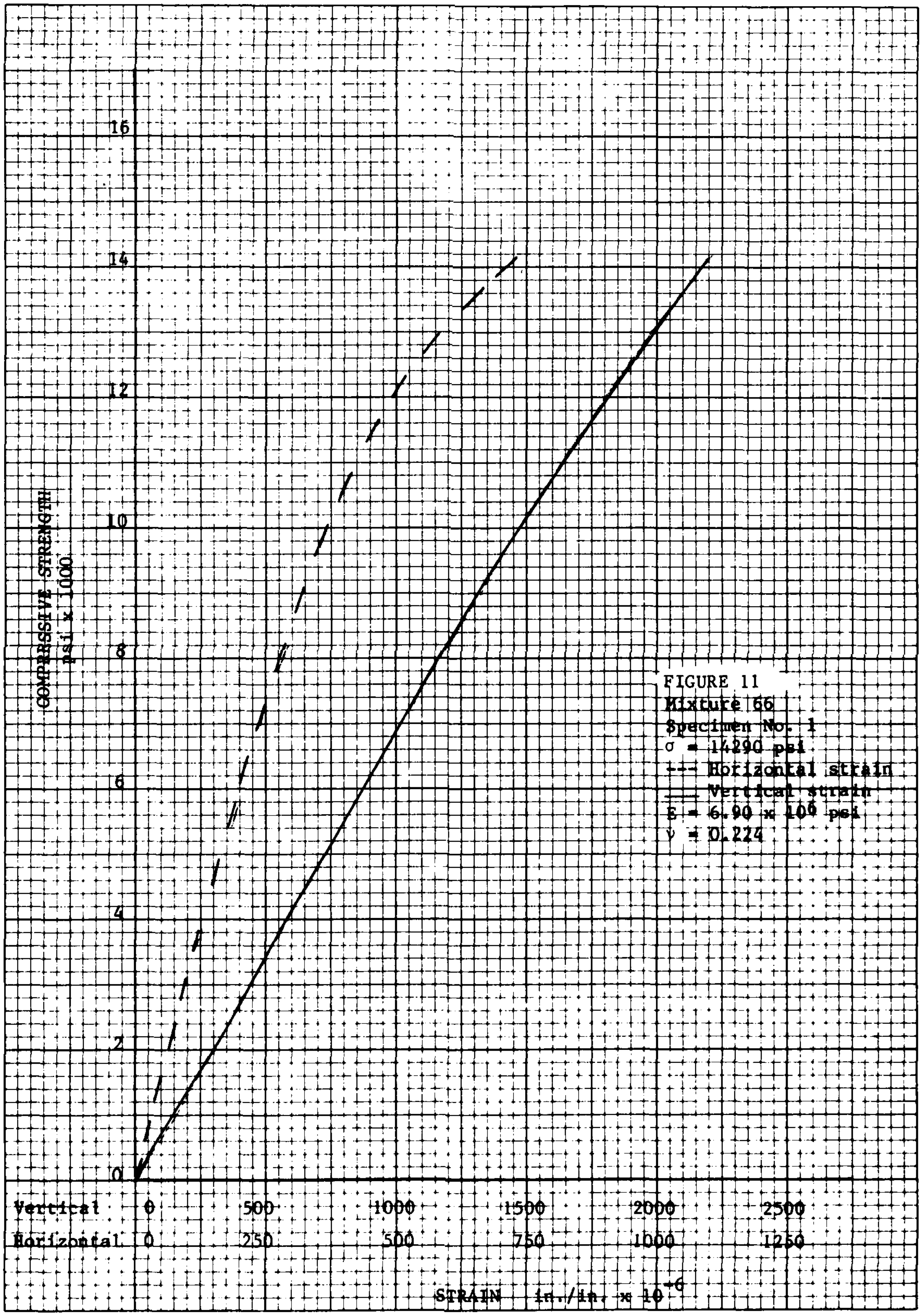
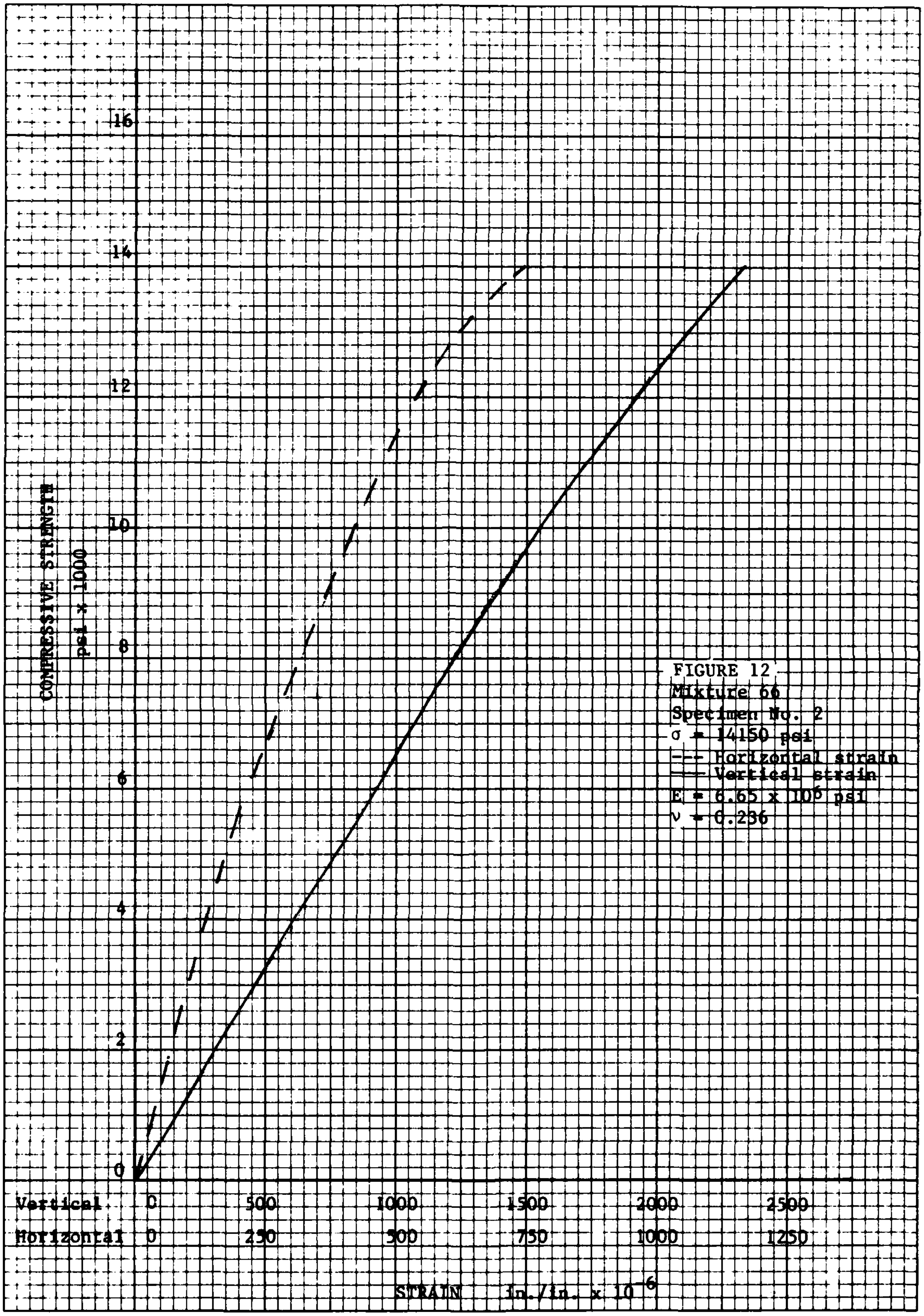


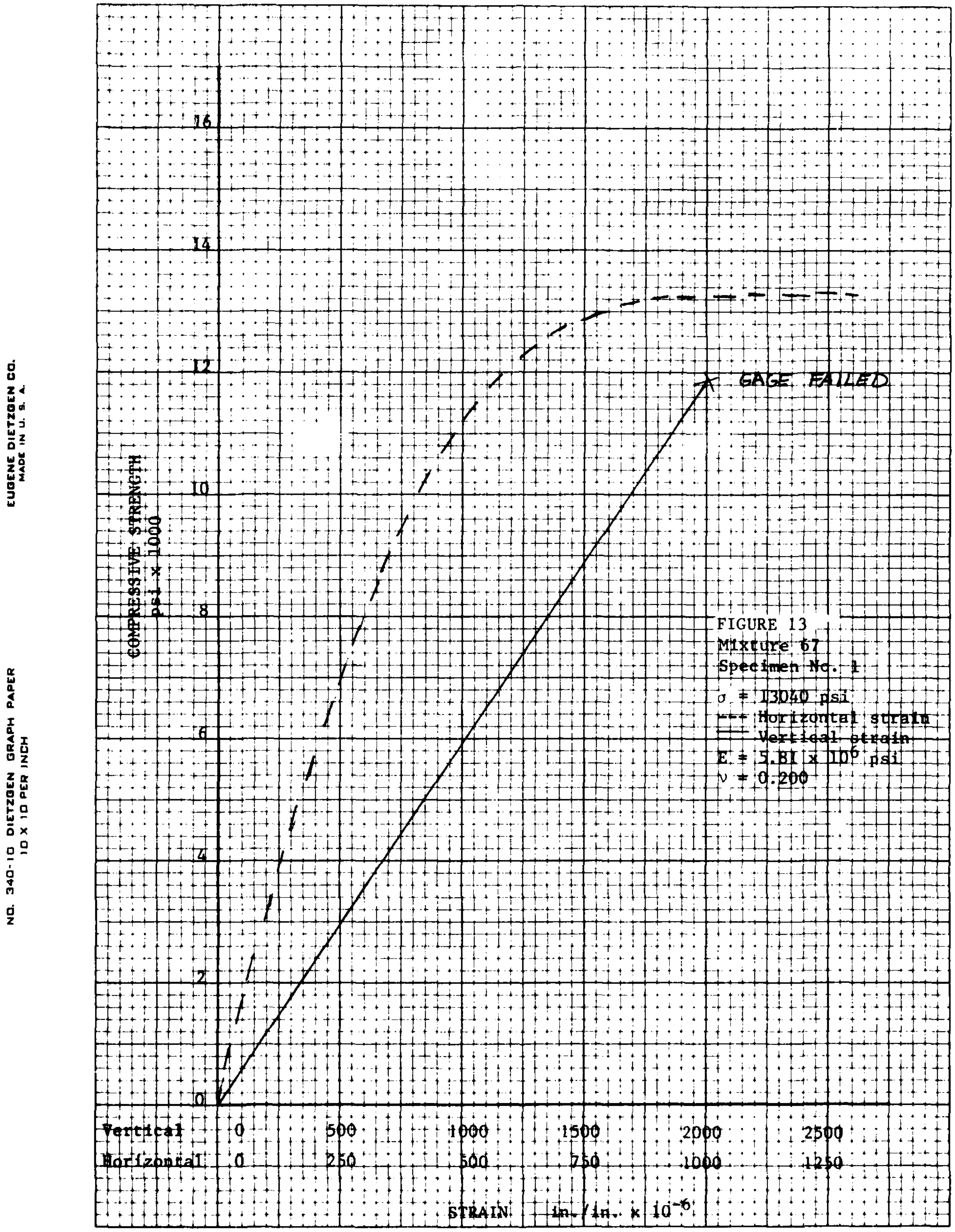
FIGURE 10
Mixture No. 65
Specimen No. 2
σ = 17,720 psi
--- Horizontal strain
___ Vertical strain
E = 6.65 x 10^6 psi
ν = 0.254

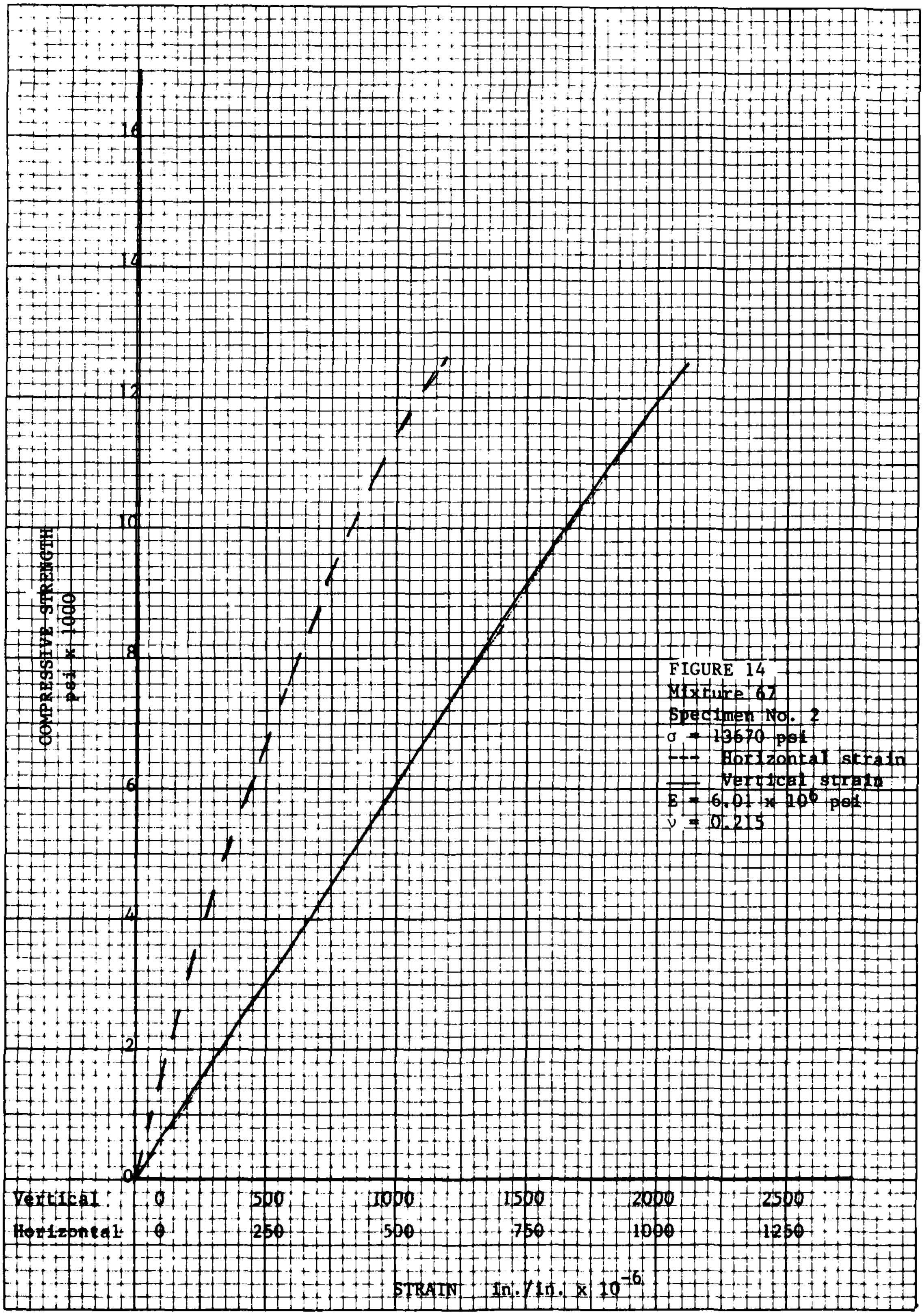


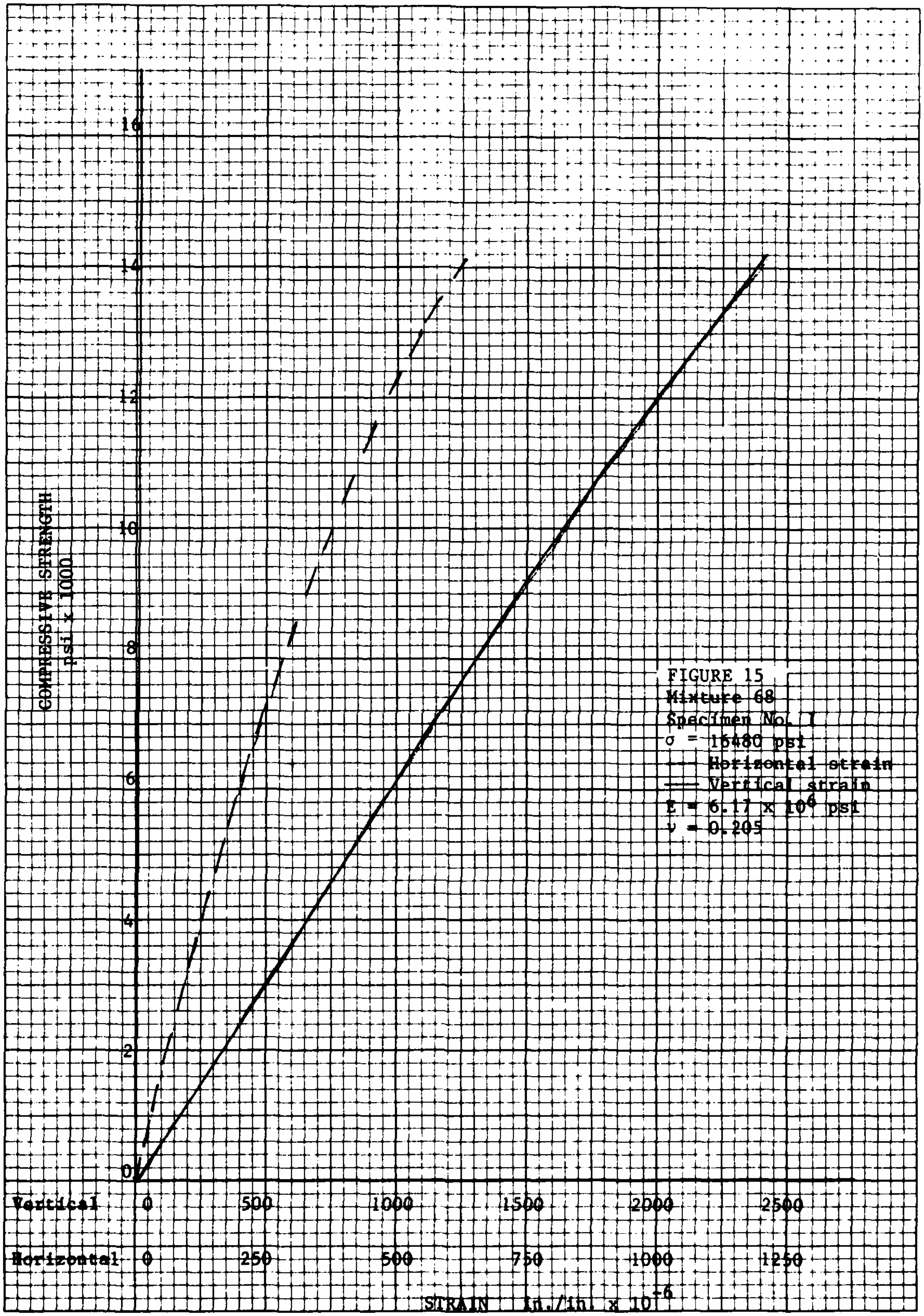
COMPRESSIVE STRENGTH
psi x 1000
16
14
12
10
8
6
4
2
0
FIGURE 11
Mixture 66
Specimen No. 1
σ = 14290 psi
Horizontal strain
Vertical strain
E = 6.90 x 10^6 psi
ν = 0.224
Vertical 0 500 1000 1500 2000 2500
Horizontal 0 250 500 750 1000 1250
STRAIN in./in. x 10^-6

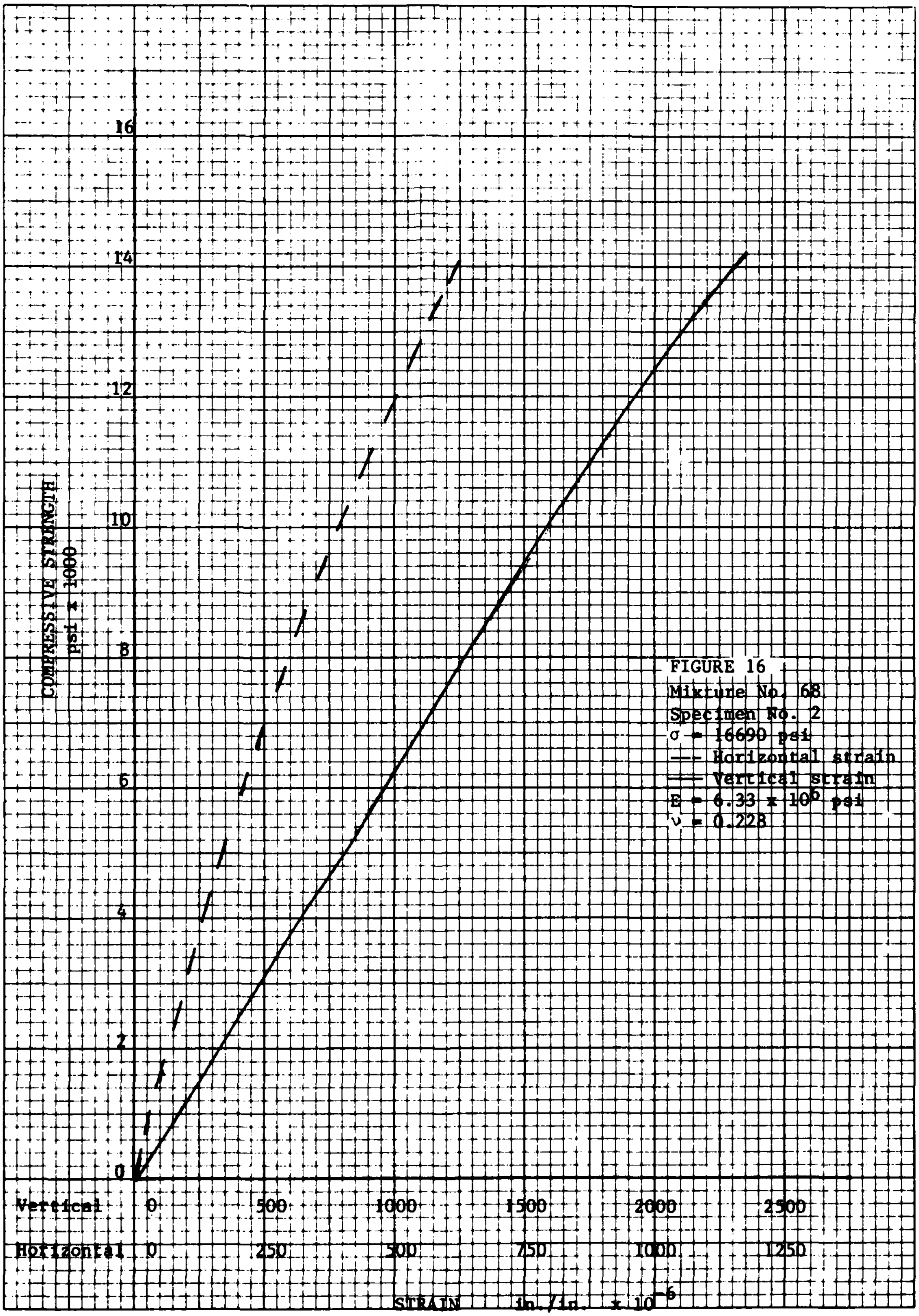


COMPRESSIVE STRENGTH
psi x 1000
0
2
4
6
8
10
12
14
16
Vertical 0 500 1000 1500 2000 2500
Horizontal 0 250 500 750 1000 1250
STRAIN in./in. x 10^{-6}
FIGURE 12
Mixture 66
Specimen No. 2
σ = 14150 psi
--- Horizontal strain
— Vertical strain
E = 6.65×10^6 psi
ν = 0.236


16
14
12
10
8
6
4
2
0
COMPRESSIVE STRENGTH
psi x 1000
GAGE FAILED
FIGURE 13
Mixture 67
Specimen No. 1
σ = 13040 psi
--- Horizontal strain
— Vertical strain
E = 5.81 x 10^6 psi
ν = 0.200
Vertical 0 500 1000 1500 2000 2500
Horizontal 0 250 500 750 1000 1250
STRAIN in./in. x 10^-6
NO. 340-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH
EUGENE DIETZGEN CO.
MADE IN U. S. A.

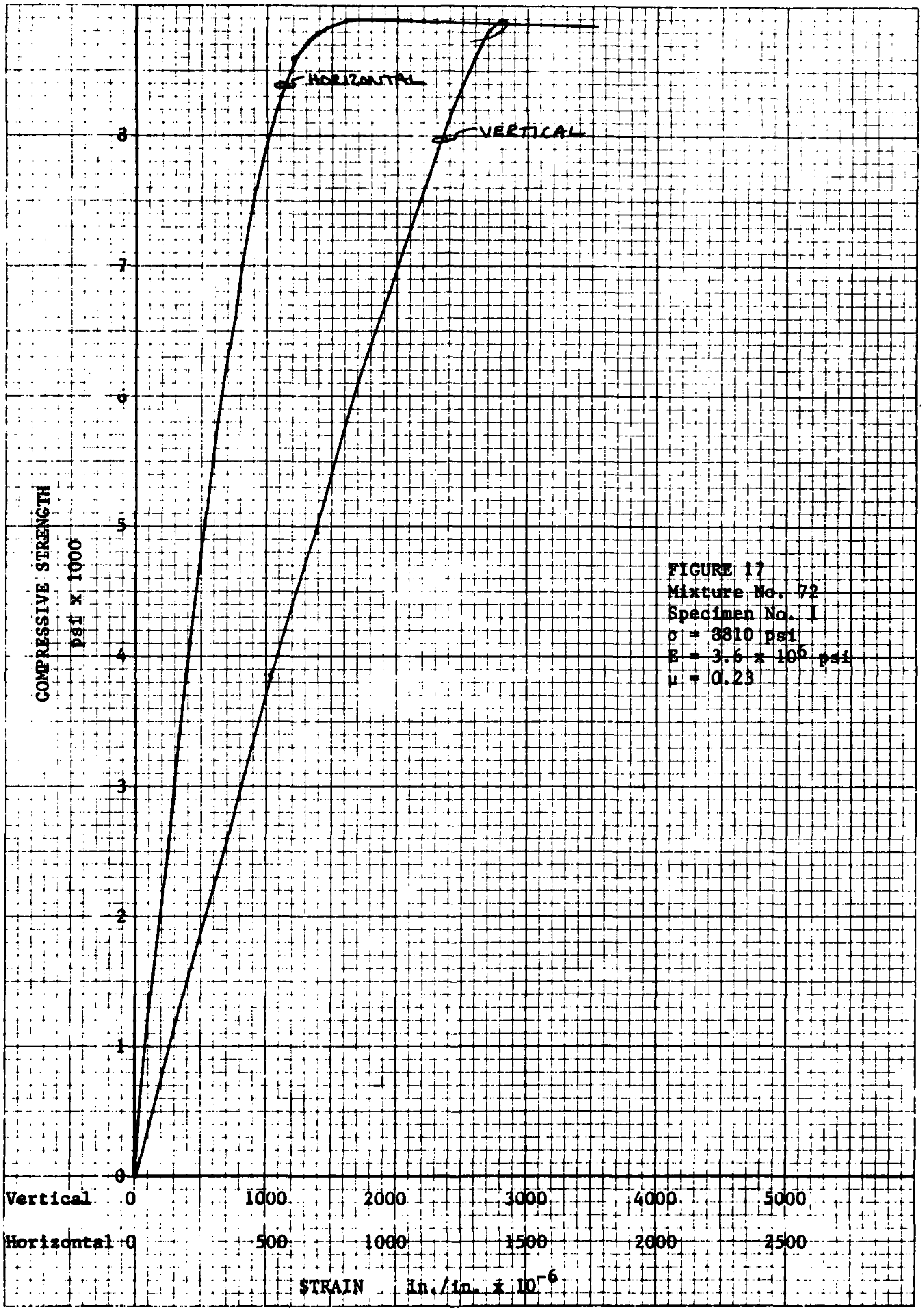

COMPRESSIVE STRENGTH
psi x 1000
0
2
4
6
8
10
12
14
16
Vertical 0 500 1000 1500 2000 2500
Horizontal 0 250 500 750 1000 1250
STRAIN in./in. x 10^{-6}
FIGURE 14
Mixture 67
Specimen No. 2
σ = 13670 psi
--- Horizontal strain
—— Vertical strain
E = 6.01×10^6 psi
ν = 0.215


COMPRESSIVE STRENGTH
psi x 1000
0
2
4
6
8
10
12
14
16
Vertical 0 500 1000 1500 2000 2500
Horizontal 0 250 500 750 1000 1250
STRAIN in./in. x 10^{-6}
FIGURE 15
Mixture 68
Specimen No. I
σ = 16480 psi
--- Horizontal strain
—— Vertical strain
E = 6.17×10^6 psi
ν = 0.205



COMPRESSIVE STRENGTH
psi x 1000
0
2
4
6
8
10
12
14
16
Vertical 0 500 1000 1500 2000 2500
Horizontal 0 250 500 750 1000 1250
STRAIN in./in. x 10^-6
Mixture No. 68
Specimen No. 2
σ = 16690 psi
Horizontal strain
Vertical strain
E = 6.33 x 10^6 psi
ν = 0.228

FIGURE 16



HORIZONTAL
VERTICAL
COMPRESSIVE STRENGTH
psi x 1000
FIGURE 17
Mixture No. 72
Specimen No. 1
σ = 8810 psi
E = 3.6 x 10^6 psi
μ = 0.23
Vertical 0 1000 2000 3000 4000 5000
Horizontal 0 500 1000 1500 2000 2500
STRAIN in./in. x 10^-6

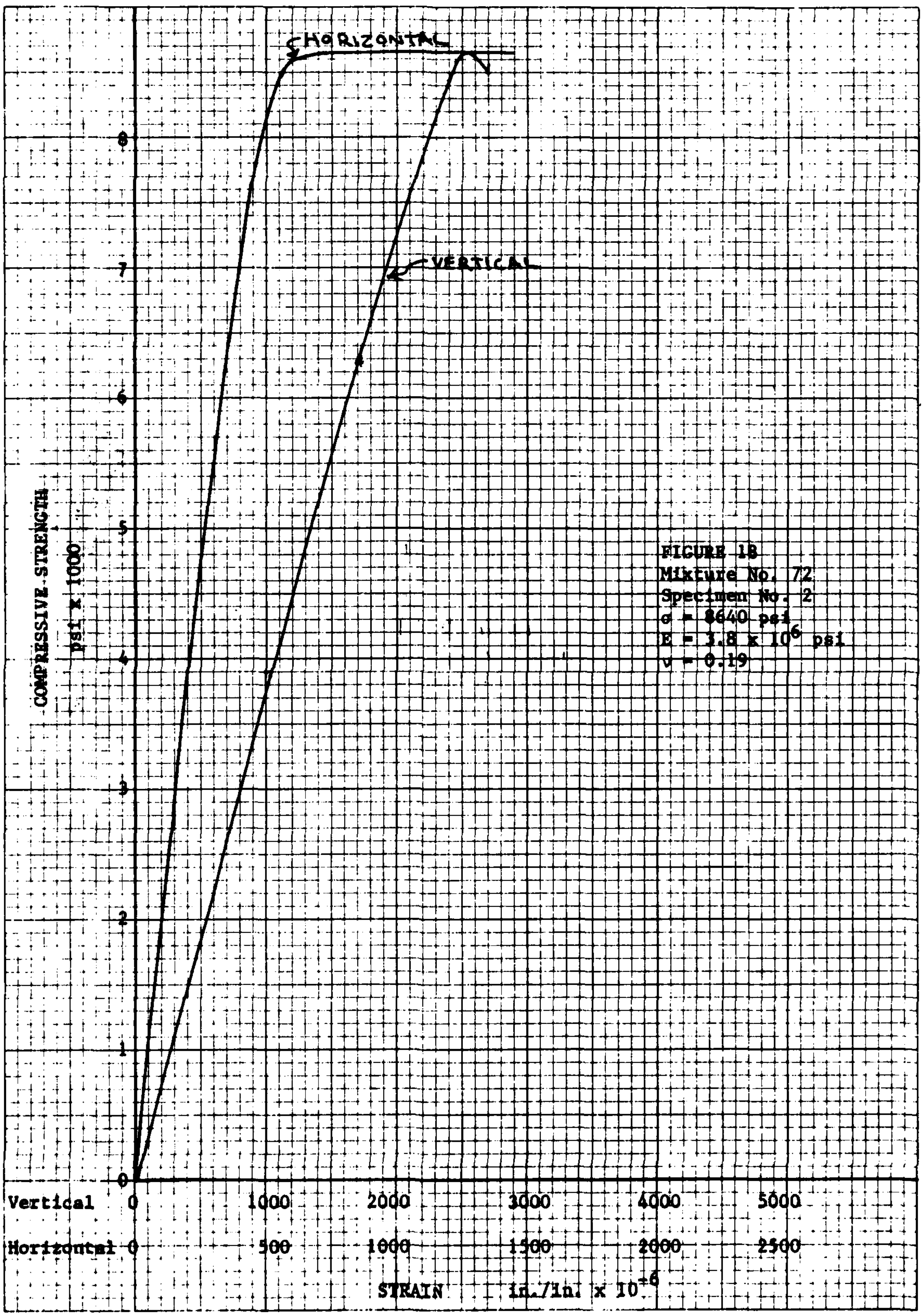


FIGURE 18
Mixture No. 72
Specimen No. 2
σ = 8640 psi
E = 3.8 x 10^6 psi
ν = 0.19

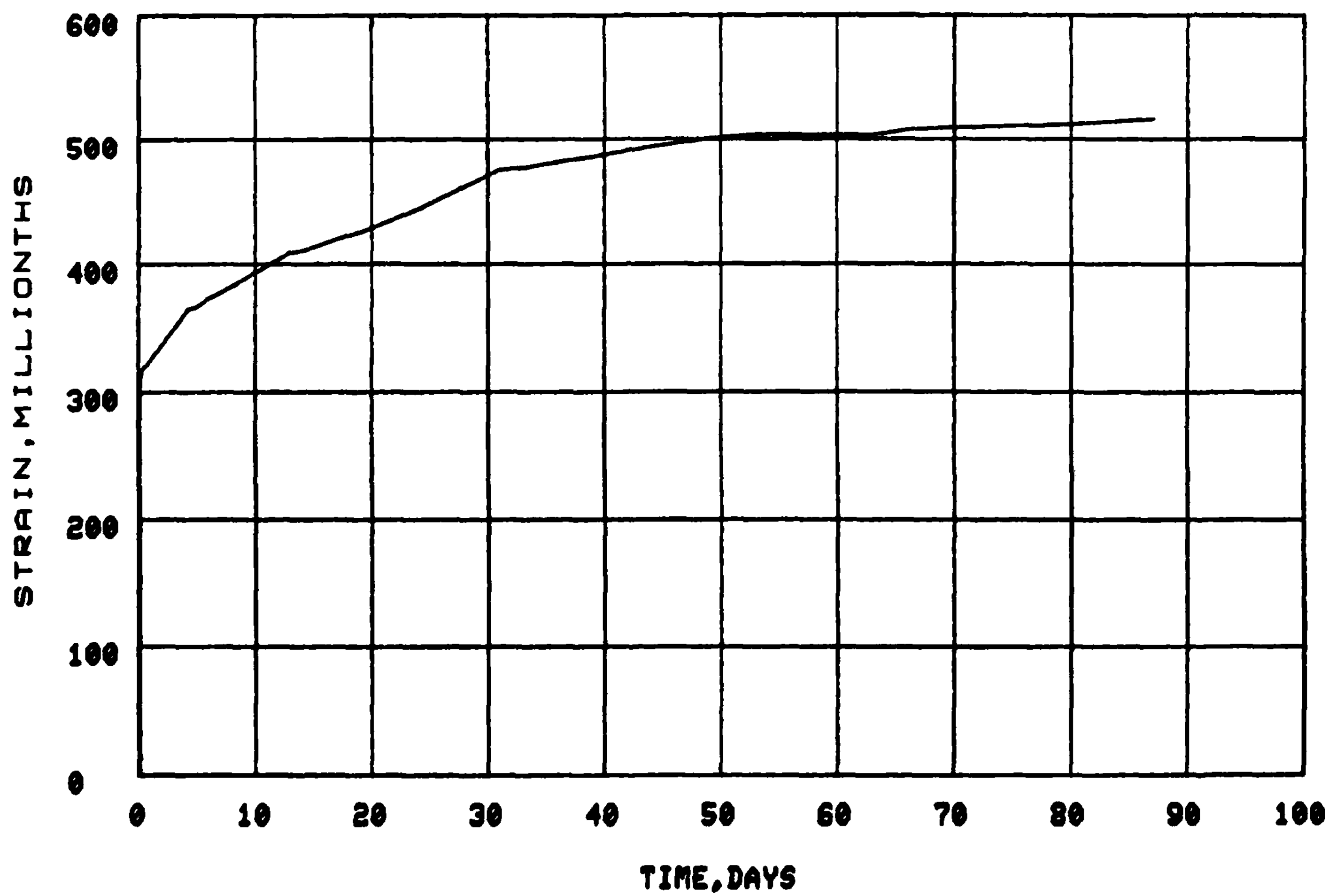


Figure 19. Total strain during loading period for mixture 22 with silica fume

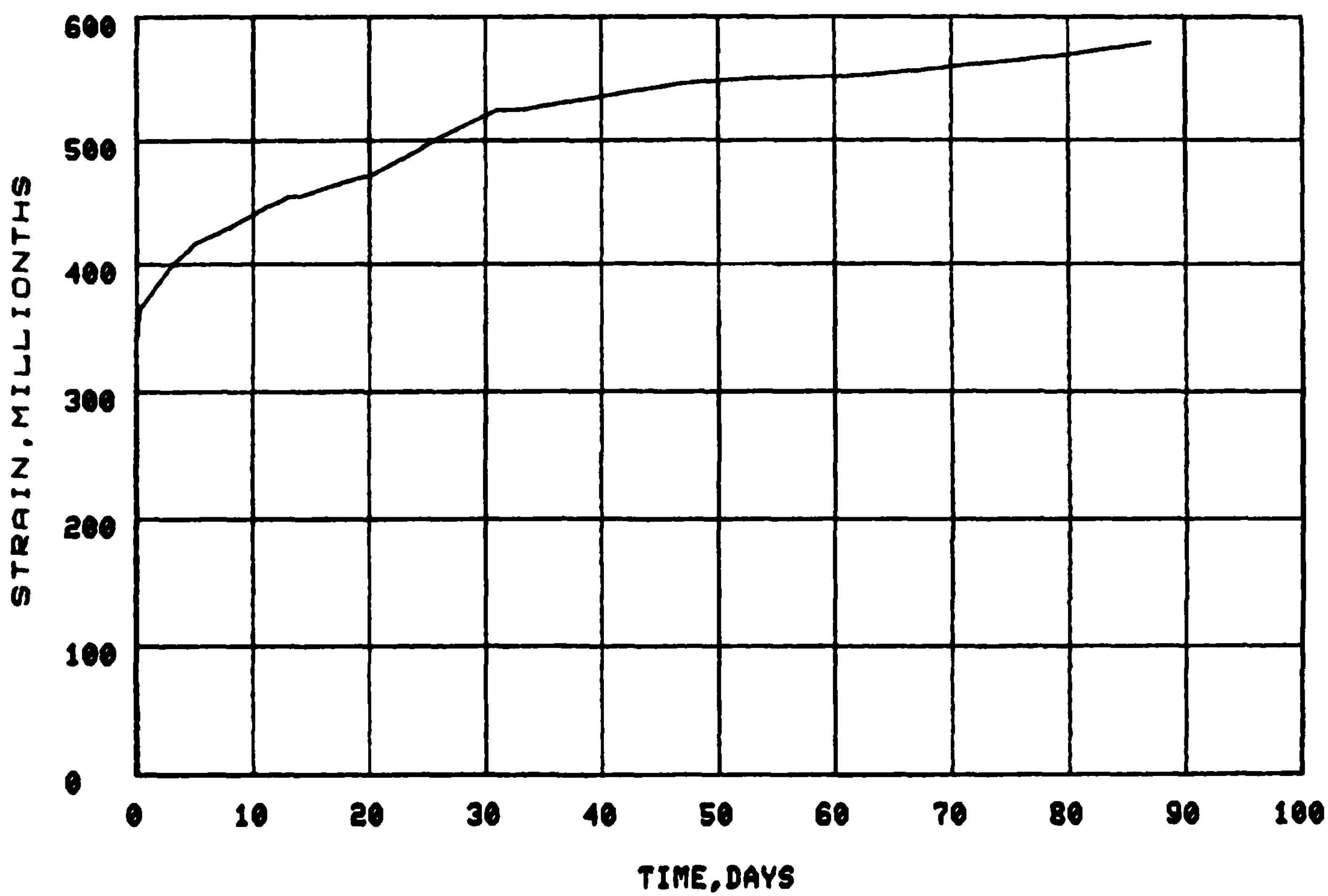


Figure 20. Total strain during loading period for mixture 22 without silica fume

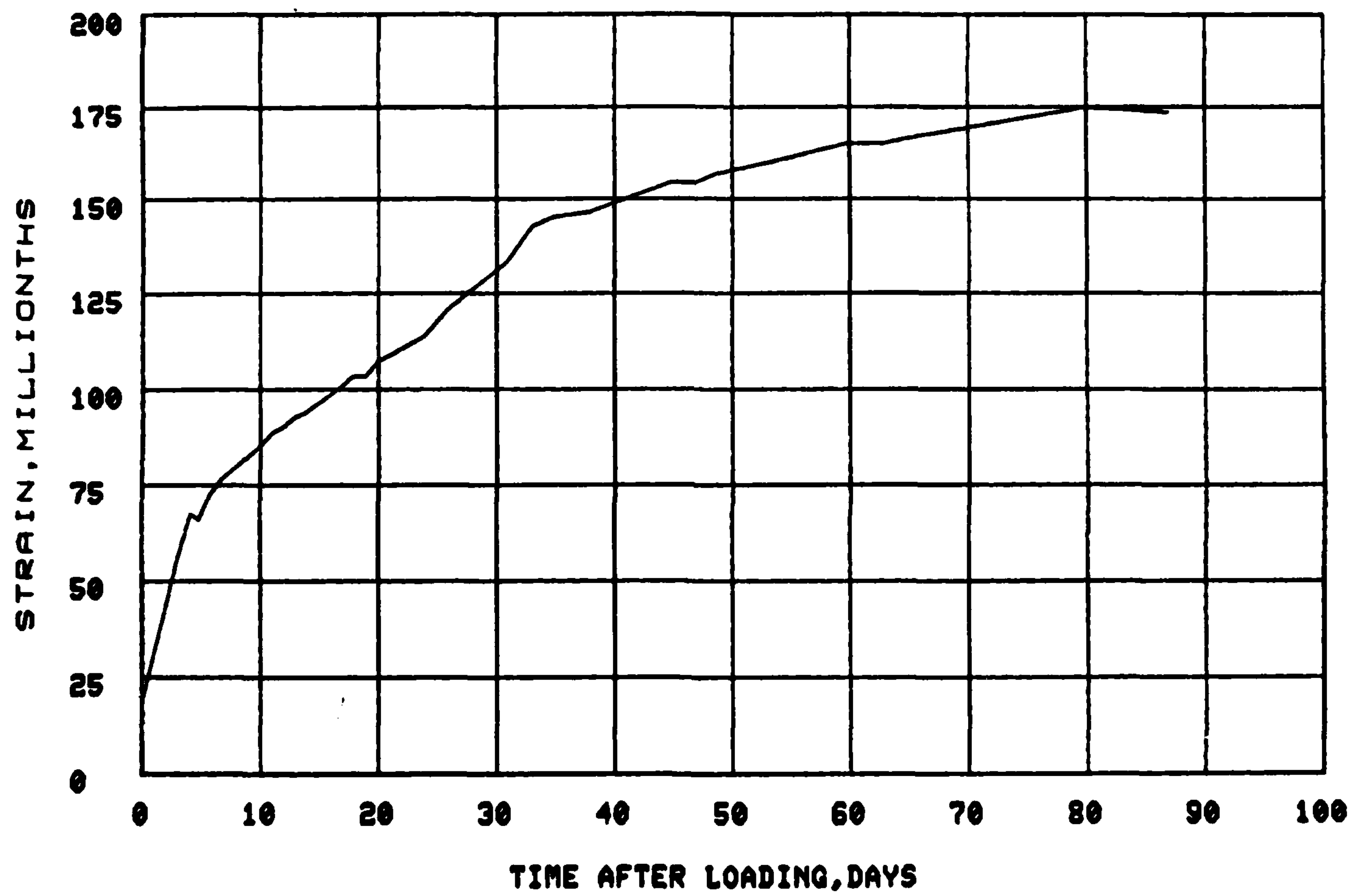


Figure 21. Corrected creep strain for mixture 22 with silica fume; loaded to 2000 psi at 14-day age (unconfined)

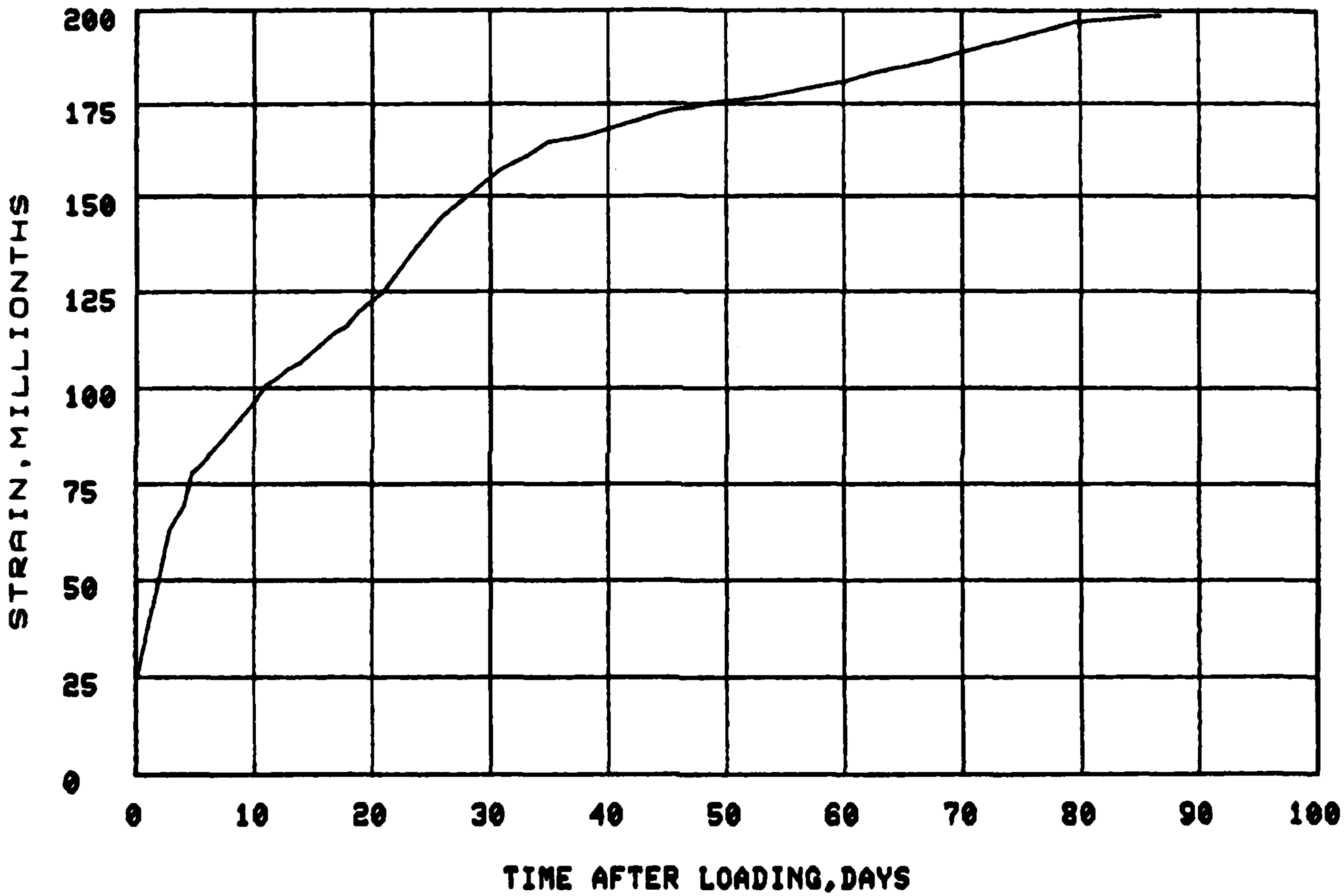


Figure 22. Corrected creep strain for mixture 22 without silica fume; loaded to 2000 psi at 14-day age (unconfined)

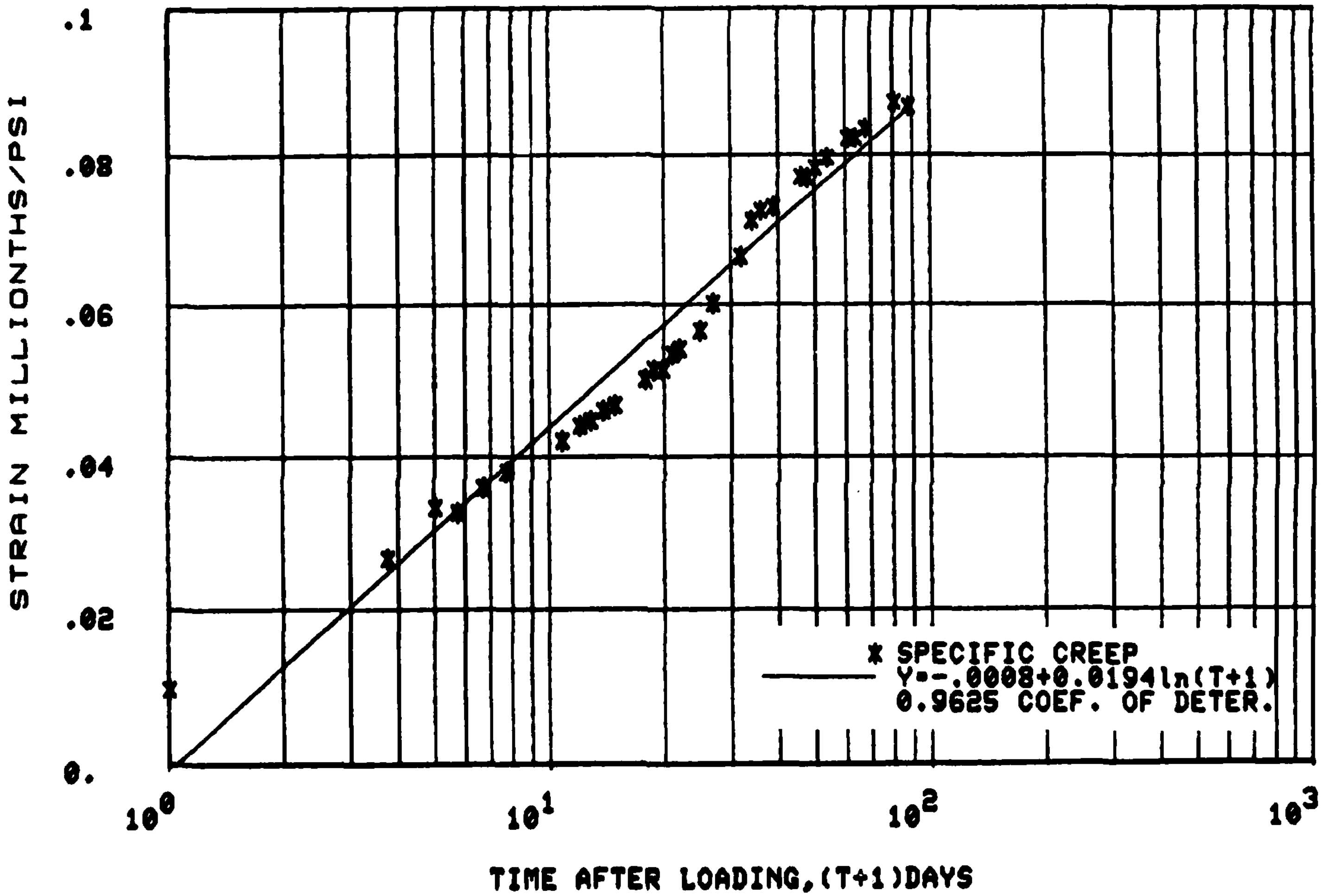


Figure 23. Specific creep for mixture 22 with silica fume; loaded to 2000 psi at 14-day age (unconfined)

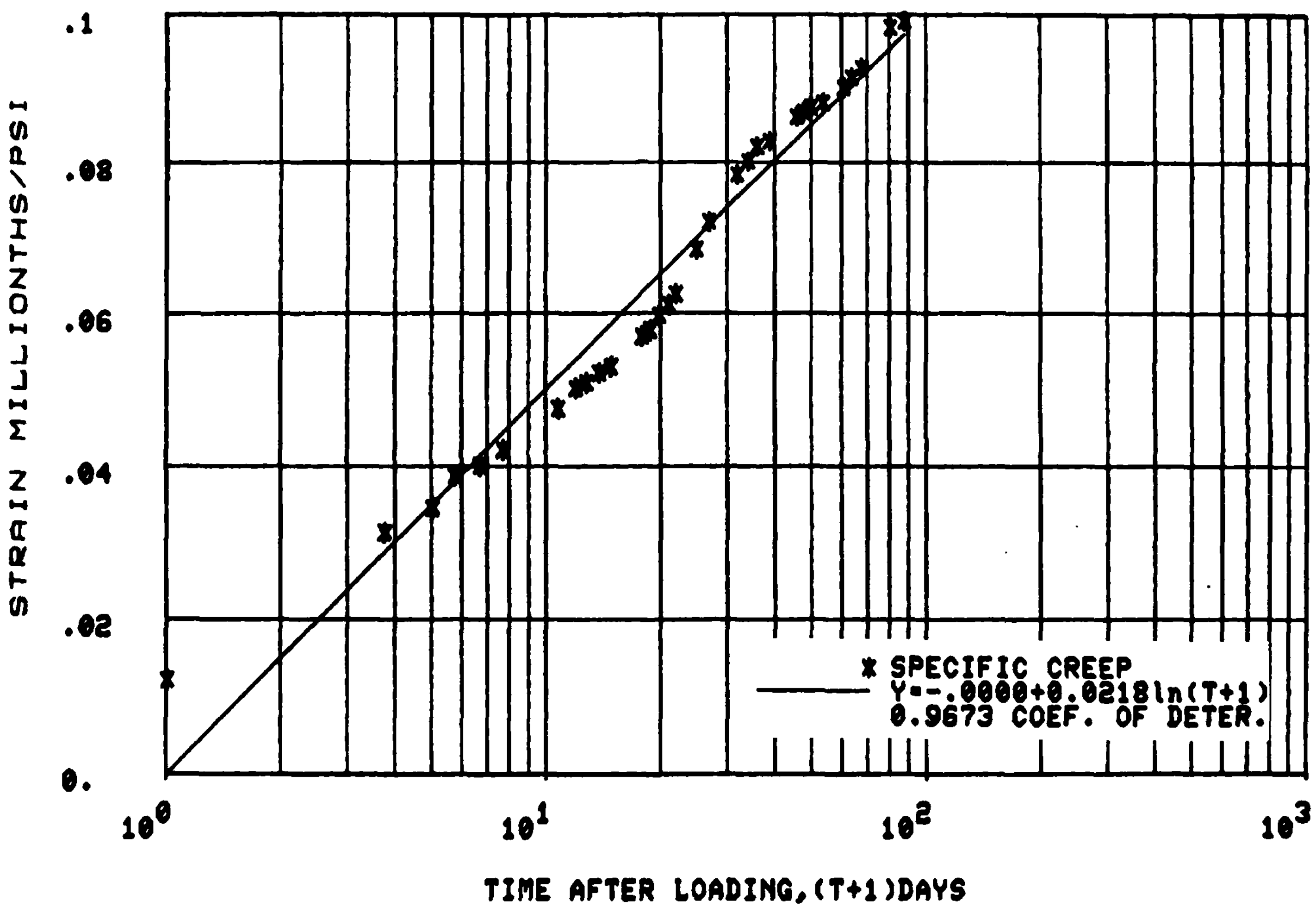


Figure 24. Specific creep for mixture 22 without silica fume; loaded to 2000 psi at 14-day age (unconfined)

END

FILMED

5-84

DTIC